PhD SCIENCE®

TEACHER EDITION

MODULE 2

Pushes and Pulls

LEVEL K

GREAT MINDS™

PhD SCIENCE®

Level K Module 2:
Pushes and Pulls

Teacher Edition

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LEVEL K MODULE 2

Pushes and Pulls

Contents

Module Overview

ESSENTIAL QUESTION

How do tugboats move cargo ships through a harbor?

Introduction

Towing a thousand-foot container ship will always be an awe-inspiring experience—the ropes as thick as tree trunks and spools the size of houses, like children's toys for giants, and everything dwarfed by the immensity of the sea.

—Burkhard Bilger (2010)

Throughout this module, students study the anchor phenomenon—tugboats moving cargo ships—and build an answer to the Essential Question: **How do tugboats move cargo ships through a harbor?** As students focus on two concepts, they build a model that represents the movement of tugboats and cargo ships through New York Harbor. Students develop an understanding of what makes objects start to move, how pushes and pulls can change the way objects move, and what happens when two objects bump into each other. By the end of the module, students use their knowledge of pushes and pulls to explain the anchor phenomenon, and they apply learned concepts to a new context in an End-of-Module Assessment. As a result of these experiences, students begin to develop an enduring understanding that pushes and pulls can start, stop, and redirect an object's movement.

Lessons 1 through 9 address the Concept 1 Focus Question: **What causes objects to start moving?** Lesson 1 introduces students to the module anchor phenomenon by using the book *Tugboat* by Michael Garland (2014) and the New York Harbor Knowledge Deck™ poster. In Lesson 2, students examine a map of New York Harbor and use a set of wooden blocks to model how tugboats could help move cargo ships through part of the harbor. Students use the ideas they generate about how one object can move another to create an initial anchor model that shows a tugboat pushing or pulling a cargo ship in the harbor. In Lesson 3, students review the anchor model and the importance of asking relevant questions, and then they develop a driving question board. They revisit the driving question board and anchor model throughout the module to build a coherent understanding of how tugboats move cargo ships through a harbor. In Lessons 4 through 6, students investigate what causes objects to start moving. First, students explore ways they can make a set of toys move. Students determine that they can sort their actions into two categories: pushes and pulls. The class then tests this finding with another object. Students record their observations of a push or pull, and they develop a broader understanding that when an object starts moving, it does so because of a push or pull. Next, to apply their learning in the context of the anchor phenomenon, students observe how a plastic tugboat can push and pull a wooden block cargo ship in water. In Lessons 7 and 8, students investigate how the strength of a push or pull on an object affects the speed of the object's movement. They determine that stronger pushes and pulls cause a table tennis ball to move faster, whereas weaker pushes and pulls cause the same ball to move slower. Students also revisit the water model to observe how the strength of pushes and pulls affects the speed of an object in water. In Lesson 9, students apply their understanding of how pushes and pulls can start movement to a new context in a Conceptual Checkpoint.

Lessons 10 through 16 address the Concept 2 Focus Question: **What causes moving objects to change direction or stop?** In Lessons 10 through 12, students explore how tugboats can use pushes and pulls to move cargo ships through a harbor and to a port. Students plan a collaborative investigation to determine how tugboats can change the direction of a cargo ship's movement. Then students conduct the investigation by using wooden block tugboats to turn a wooden block cargo ship. Students also revisit the water model to analyze how pushes and pulls can turn a wooden block cargo ship in water. In Lessons 13 through 15, students plan and conduct an investigation to explore how a tugboat can use pushes and pulls to slow down and stop a cargo ship. They revisit the water model once more and predict how the plastic tugboat can stop the wooden block cargo ship in water. Students also extend their understanding of pushes by exploring what happens when two objects bump into each other; students discover that each object pushes on the other, which can cause changes in movement. In Lesson 16, students apply their understanding of how pushes and pulls can change movement to a new context in a Conceptual Checkpoint.

In Lessons 17 through 20, students participate in an Engineering Challenge in which the goal is to help a tugboat stop close to its dock. To help the tugboat, students use their understanding of what happens when two objects bump into each other along with their knowledge of how the strength of a push affects an object's movement. Students apply the engineering design process to create a model dock cushion that changes how the tugboat and dock push each other on contact. In Lesson 17, students define the problem and consider how a dock cushion could solve it. Next, they determine that measuring how far a model tugboat bounces after bumping into each cushion will help them compare their cushions. Then, in Lesson 18, students test various materials, sketch their design plans, and predict the effectiveness of their cushions. After creating their cushions during Lesson 19, students test their designs and gather evidence of how well the designs work. Students then have a chance to improve their designs and conduct more tests. Finally, in Lesson 20, students share their cushions with the class. They analyze their data by comparing numerical results, and they see which materials helped the model tugboat stop closer to its dock.

Lessons 21 through 23 conclude the module. In Lesson 21, students participate in a Socratic Seminar and use their learning from throughout the module to answer the Essential Question: **How do tugboats move cargo ships through a harbor?** In Lesson 22, students apply their conceptual understandings in an End-of-Module Assessment. Finally, in Lesson 23, the class debriefs the End-of-Module Assessment to clarify misconceptions, and students reflect on their work throughout the module to reveal how they built their knowledge.

Module Map

Anchor Phenomenon: Tugboats Moving Cargo Ships

Essential Question: How do tugboats move cargo ships through a harbor?

Pushes and pulls can cause objects to start moving and can cause their movement to change.

Concept 1: Starting Movement

Focus Question: What causes objects to start moving?

Pushes and pulls can cause objects to start moving. The strength of the pushes and pulls can affect the speed of the objects.

Science Topic	Phenomenon Question	Student Learning	Performance Expectations*
Tugboats Moving Cargo Ships	What do tugboats do?	Tugboats help cargo ships move through harbors. ▪ Lesson 1: Explore what tugboats do in harbors. ▪ Lesson 2: Construct an anchor model of a tugboat moving a cargo ship. ▪ Lesson 3: Ask questions about tugboats moving cargo ships.	K-PS2-1
Making Objects Start to Move	How do tugboats make cargo ships start to move?	Pushes and pulls can cause objects to start moving. ▪ Lesson 4: Categorize actions as pushes or pulls. ▪ Lesson 5: Record and reflect on observations of pushes and pulls. ▪ Lesson 6: Apply new understanding of pushes and pulls to the anchor phenomenon.	K-PS2-1
Push and Pull Strength	How can a tugboat make a cargo ship move fast or slow?	Stronger pushes and pulls cause objects to move faster than weaker pushes and pulls. ▪ Lesson 7: Investigate stronger and weaker pushes. ▪ Lesson 8: Apply knowledge of stronger and weaker pushes and pulls to the anchor phenomenon.	K-PS2-1

* The bold Performance Expectations identify lessons in which students should demonstrate mastery of the relevant Disciplinary Core Idea(s). In other lessons, students develop their knowledge of the relevant Disciplinary Core Idea(s). Students integrate Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas in all lessons. In agreement with the guidance of the Next Generation Science Standards (NGSS), students may apply Practices and Concepts other than those named in the Performance Expectations (NGSS Lead States 2013).

Science Topic	Phenomenon Question	Student Learning	Performance Expectations
Starting Movement	How can a push or a pull help in a skateboard race?	Pushes and pulls can cause objects to start moving. The strength of the pushes and pulls can affect the speed of the objects. ▪ Lesson 9: Use knowledge of pushes and pulls to determine the outcome of a skateboard race.	**K-PS2-1**

Concept 2: Changing Movement

Focus Question: What causes moving objects to change direction or stop?

Pushes and pulls can cause moving objects to change direction or stop.

Science Topic	Phenomenon Question	Student Learning	Performance Expectations
Changing Direction	How can tugboats turn a cargo ship?	Pushes and pulls can cause moving objects to change direction. ▪ Lesson 10: Plan an investigation to determine how tugboats can turn a cargo ship. ▪ Lesson 11: Investigate how tugboats use pushes and pulls to turn a cargo ship. ▪ Lesson 12: Apply new learning about changing the direction of an object's movement to the anchor model.	K-PS2-1
Slowing Down and Stopping	How can a tugboat make a cargo ship slow down and stop?	Pushes and pulls can cause moving objects to slow down and stop. ▪ Lesson 13: Plan an investigation to explore how a tugboat can make a cargo ship slow down and stop. ▪ Lesson 14: Investigate how a tugboat uses pushes and pulls to make a cargo ship slow down and stop. ▪ Lesson 15: Identify simultaneous pushes between a pair of objects.	K-PS2-1
Changing Movement	How do people use pushes and pulls when they play soccer?	Pushes and pulls can cause moving objects to change direction or stop. ▪ Lesson 16: Identify how soccer players use pushes and pulls to change the movement of the ball.	**K-PS2-1**

Application of Concepts

Task	Phenomenon Question	Student Learning	Performance Expectations
Engineering Challenge	How can we help a tugboat stop close to a dock?	People can use the engineering design process to create a device that helps a tugboat stop close to a dock. ▪ Lessons 17–20: Apply the engineering design process to create a model cushion that helps a tugboat stop close to a dock.	**K-PS2-1** **K-PS2-2** **K-2-ETS1-2**
End-of-Module Socratic Seminar, Assessment, and Debrief	How do people use pushes and pulls to play carnival games?	Pushes and pulls can cause objects to start moving and can cause their movement to change. ▪ Lesson 21: Explain how tugboats use pushes and pulls to help move cargo ships. (Socratic Seminar) ▪ Lesson 22: Explain how people use pushes and pulls to play carnival games. (End-of-Module Assessment) ▪ Lesson 23: Explain how pushes and pulls can start, stop, or change the direction of an object's movement. (End-of-Module Debrief)	**K-PS2-1** **K-PS2-2**

Focus Standards

Performance Expectations

K-PS2 Motion and Stability: Forces and Interactions

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

K–2-ETS1 Engineering Design

K–2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

Three Dimensions: At a Glance

Science and Engineering Practices (SEPs)	Disciplinary Core Ideas (DCIs)	Crosscutting Concepts (CCs)
SEP.1: Asking Questions and Defining Problems	PS2.A: Forces and Motion	CC.1: Patterns
SEP.3: Planning and Carrying Out Investigations	PS2.B: Types of Interactions	CC.2: Cause and Effect
SEP.4: Analyzing and Interpreting Data	PS3.C: Relationship Between Energy and Forces	CC.3: Scale, Proportion, and Quantity
SEP.5: Using Mathematics and Computational Thinking	ETS1.A: Defining Engineering Problems	
	ETS1.B: Developing Possible Solutions	

Three Dimensions: In Detail

Science and Engineering Practices

SEP.1: Asking Questions and Defining Problems

- Ask questions based on observations to find more information about the natural and/or designed world(s).

SEP.3: Planning and Carrying Out Investigations

- Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.

SEP.4: Analyzing and Interpreting Data

- Record information (observations, thoughts, and ideas).

SEP.5: Using Mathematics and Computational Thinking

- Use counting and numbers to identify and describe patterns in the natural and designed world(s).

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Pushes and pulls can have different strengths and directions.
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.

PS2.B: Types of Interactions

- When objects touch or collide, they push on one another and can change motion.

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things speed up or slow down more quickly.

ETS1.A: Defining Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.

ETS1.B: Developing Possible Solutions

- Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.

Crosscutting Concepts

CC.1: Patterns

- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

CC.2: Cause and Effect

- Events have causes that generate observable patterns.

CC.3: Scale, Proportion, and Quantity

- Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).

Building Knowledge and Skills across Levels

Throughout Kindergarten, students build knowledge and skills associated with the Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

Science and Engineering Practices

In this module, students engage in the practice of asking questions (SEP.1) about their observations to help them learn about the world. During the Concept 1 Conceptual Checkpoint, students ask questions about pushes and pulls to help them figure out which object is moving faster. In Levels 3 through 5, students will expand their inquiry skills by distinguishing between questions that are testable and those that are not.

Throughout this module, students plan and carry out investigations (SEP.3) to help them understand how pushes and pulls can start or change movement. As the module progresses, students gradually assume more responsibility during the planning phases of their investigations. After carrying out these investigations, students compare what they observe. In Levels 3 through 5, students will build on their investigation skills by making measurements to produce data. Students will use this data as evidence to support or reject explanations or design solutions.

In Kindergarten, students engage in the practice of analyzing and interpreting data (SEP.4) to help them make sense of the relationship between movement and pushes and pulls. Students record observations of moving objects and share their thoughts about the causes of movement. In Levels 3 through 5, students will organize data they have collected to help reveal patterns that can indicate relationships.

In the Engineering Challenge, students use counting and numbers (SEP.5) to help them identify patterns in the designed world. Students measure the distance that the model tugboat bounces after bumping into their model dock cushions, and they use their measurements to compare the success of different dock cushion designs. In Levels 3 through 5, students will further integrate their mathematics skills and use graphs to depict measurements of various physical properties.

Disciplinary Core Ideas

The Kindergarten focus on pushes, pulls, and movement lays the foundation for a more sophisticated understanding both of how objects interact and of how forces and energy relate to each other.

In this module, students learn that pushes and pulls can make an object start moving, can have different strengths, and can make a moving object turn or slow down and stop (PS2.A). As students explore different ways to start or change an object's movement, they identify the cause and effect relationship between a push or pull and the resulting movement. In Level 3, students will build on their understanding of forces and recognize that there are often multiple forces acting on an object. They will determine that they can explain changes in motion or the reason an object is at rest by finding the sum of these forces. Students will also identify patterns of motion that they can use to predict future motion.

In Kindergarten, students determine that when two objects bump into each other, each object pushes on the other, which can lead to changes in movement (PS2.B). In Level 3, students will expand their knowledge beyond these contact forces. Students will learn about other forces that can act over a distance, such as gravity, electric force, and magnetic force, and they will determine that Earth's gravitational force pulls objects toward Earth's center.

In this module, students also explore how the strength of a push or pull on an object affects the object's speed (PS3.C). Students determine that stronger pushes and pulls cause objects to move faster than weaker pushes and pulls. In Level 4, students will expand their knowledge of the relationship between energy and forces as they further explore collisions. They will determine that when objects collide, the impact transfers energy that can change the motion of the objects.

Crosscutting Concepts

Throughout this module, students develop a deeper understanding of the Disciplinary Core Ideas by applying the Crosscutting Concepts of Patterns (CC.1) and Cause and Effect (CC.2). As students investigate how pushes and pulls can start and change the movement of an object, they begin to notice patterns that help them recognize cause and effect relationships. In Levels 3 through 5, students will continue to identify and test cause and effect relationships, which they use to explain changes over time. Students will also recognize that events that often occur together may or may not be related by cause and effect.

Furthermore, as Kindergarten students observe the relationship between the strength of a push or pull and the resulting effect on an object's movement, they deepen their understanding of scale, proportion, and quantity (CC.3). Students use comparative terms, such as *stronger* and *weaker* to describe a push or pull's strength and *faster* and *slower* to describe an object's speed. In Levels 3 through 5, students will recognize that objects vary immensely in size and that events vary immensely in duration. To help comprehend these scales, students will measure physical quantities, such as weight and time, by using standard units.

Why?

Why do students study tugboats and cargo ships as the anchor phenomenon?

In this module, students explore the Disciplinary Core Idea PS2.A, Forces and Motion, and focus on the ways that pushes and pulls can start the motion of an object and change the motion of an object. The world is rich with push and pull interactions. The benefit of studying tugboats and cargo ships is that the pushes and pulls between the vessels occur over long stretches of time and space. Because tugboats apply forces for prolonged periods, students can easily see the sustained effects that these pushes and pulls have on cargo ship motion. Students can then use these concrete, visible examples of sustained pushes and pulls to make sense of much quicker interactions, such as collisions between two objects.

Why don't students use the term *force* in the module?

Students can study countless interactions in which an object's movement changes because of a push or pull from another object. To explain the phenomena in this module, the familiar terms *push* and *pull* are sufficient. In later levels, students may notice that the terms *push* and *pull* do not seem to adequately describe the cause of movement in every case. Common usage of the terms *push* and *pull* as actions makes them seem insufficient when describing pushes or pulls that arise passively because of an object's inherent state. For example, all objects generate a gravitational force due to their mass, and some objects can generate a magnetic force due to their structure. Students will use the term *force* when they learn about these more advanced physics phenomena. Throughout this module, students may share or ask questions about changes in movement that they cannot easily explain by citing a push or pull. It is appropriate for students to test their learning in new situations and to recognize that having unanswered questions means they have more to learn about the world around them.

Why don't students learn about gravity as a pull?

Young students need to experience science through concrete, hands-on examples. To help students develop an understanding of fundamental concepts, each of the interactions in this module involves a pair of concrete and accessible objects, such as a wooden block tugboat and a wooden block cargo ship, a craft stick and a table tennis ball, and a Hall's car and a cushion. By comparison, the concept of gravity is more abstract because gravity acts at a distance and is not visible; only its effects are visible. Additionally, gravity is less accessible because in everyday examples of gravity between two objects, Earth pulls an object toward Earth's center, so one of the objects is Earth. Students will develop an understanding of gravity in Levels 3 through 5, after they develop foundational knowledge about how pushes and pulls can cause movement.

Key Terms

In this module, students learn the following terms through investigations, models, explanations, class discussions, and other experiences.

- Direction
- Object
- Pull
- Push
- Speed
- Strength

Safety Considerations

The safety and well-being of students are of utmost importance in all classrooms, and educators must act responsibly, prudently, and proactively to safeguard students. Science investigations frequently include activities, demonstrations, and experiments that require extra attention to safety measures. Educators must do their best to ensure a safe classroom environment.

The hands-on, minds-on activities of Module 2 involve working with small objects, working with water, and pushing and pulling objects. Some of the more important safety aspects to implement in Module 2 follow.

1. **Teachers must explain all safety considerations to students and review all safety expectations with them before each activity.**
2. **Students must carefully listen to and follow all teacher instructions.** Instructions may be oral, on classroom postings, or written in the Science Logbook or other handouts.
3. **Students must demonstrate appropriate classroom behavior (e.g., no running, jumping, or pushing) during science investigations.** Students must handle all supplies and equipment carefully and respectfully. Additionally, students should do their best to avoid touching their face during investigations.
4. **Students and teachers must put away all food and drinks during science investigations.** Investigation materials can easily contaminate food and drinks. Also, spilled food or drinks can disrupt investigations.
5. **Students must never place materials in their mouth during a science investigation.**
6. **Students and teachers must wear personal protective equipment (e.g., safety goggles) throughout investigations that require this equipment.** Students and teachers must wear safety goggles whenever they work with objects with sharp points (e.g., wires, toothpicks), materials made up of tiny pieces (e.g., sand), glass, projectiles (objects that move through the air), and liquids other than pure water.
7. **Students must immediately inform teachers of any spills, breakages, or materials falling to the floor. Students must then follow all teacher instructions for cleaning up, including allowing teachers to clean up spills, breakages, and other materials that may be dangerous.** During investigations, items can fall to the floor even when everyone is careful. Immediate removal of debris from the floor is essential to help prevent injury.
8. **Students must follow teacher instructions regarding cleanup at the end of each investigation.** Teachers may ask students to return materials to specific storage locations in the classroom or to clean the surfaces of their desks with provided materials (e.g., water and paper towels). After completion of the investigation and cleanup, students must thoroughly wash their hands.
9. **Teachers must monitor student activity on the internet.** If students must access the internet for science research purposes, teachers must monitor students' activity to ensure conformation with school and district policies.

More information on safety in the elementary science classroom appears in the Implementation Guide. Teachers should always follow the health and safety guidelines of their school or district. For additional information on safety in the science classroom, consult the National Science Teaching Association website (http://www.nsta.org/) or other resources.

Additional Reading for Teachers

- "In Ports Everywhere, It's Push Versus Pull" by C. Claiborne Ray (*New York Times*): http://phdsci.link/1607
- "How Does Force Affect Motion?" by Gerald Darling (in *Science and Children*)

Lessons 1–3
Tugboats Moving Cargo Ships

Prepare

Throughout this module, students explore how pushes and pulls affect the movement of objects (PS2.A). Lesson 1 introduces the module anchor phenomenon: tugboats moving cargo ships through a harbor. Students first learn about the phenomenon by listening to two readings of *Tugboat* by Michael Garland (2014). This book features repeated instances of tugboats moving other vessels (CC.1) by pushing or pulling them. In Lesson 2, students explore the phenomenon further by examining a map of New York Harbor. They use wooden blocks and a map of the harbor to model how tugboats might help move cargo ships. Students then use the ideas they generate to develop an anchor model. In Lesson 3, students use their observations from across these first three lessons to ask questions (SEP.1) and to build a driving question board.

Concept 1: Starting Movement

Focus Question

What causes objects to start moving?

Phenomenon Question

What do tugboats do?

Student Learning

Knowledge Statement

Tugboats help cargo ships move through harbors.

Objectives

- Lesson 1: Explore what tugboats do in harbors.
- Lesson 2: Construct an anchor model of a tugboat moving a cargo ship.
- Lesson 3: Ask questions about tugboats moving cargo ships.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Developing)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.1: Asking Questions and Defining Problems ▪ Ask questions based on observations to find more information about the natural and/or designed world(s). SEP.2: Developing and Using Models ▪ Distinguish between a model and the actual object, process, and/or events the model represents.	PS2.A: Forces and Motion ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	CC.1: Patterns ▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

Materials

		Lesson 1	Lesson 2	Lesson 3
Student	Map model materials (1 set per group): prepared chenille stem piece (1), vinyl harbor map (1), prepared wooden block cargo ship (1), prepared wooden block tugboat (1)		●	
Teacher	*Tugboat* (Garland 2014)	●		●
	New York Harbor Knowledge Deck poster	●		●
	Staten Island and New York Harbor Map (Lesson 2 Resource A)		●	
	Map model preparation: $\frac{3}{4}$″ vinyl-coated screw-in hooks (4 per group), 3 cm × 5 cm × 1.5 cm wooden block (1 per group), 5 cm × 15 cm × 2 cm wooden block (1 per group), 12″ chenille stem (cut into 4″ pieces, 1 piece per group), cargo ship cutout from Lesson 2 Resource B (1 per group), tugboat cutout from Lesson 2 Resource B (1 per group), glue, ruler (1, optional), scissors (1)		●	
	Anchor model materials: cargo ship cutout from Lesson 2 Resource B (1), blue tugboat cutout from Lesson 2 Resource B (1), vinyl harbor map (1), marker (1), masking tape		●	
Preparation	Prepare cargo ship cutouts and tugboat cutouts. (See Lesson 2 Resource B.)		●	
	Prepare map models. (See Lesson 2 Resource C.)		●	
	If the class is not using the Module 2 kit, prepare harbor map sketches as alternatives to the vinyl harbor maps. (See Lesson 2 Resource D.)		●	

Lesson 1

Objective: Explore what tugboats do in harbors.

Agenda

Launch (5 minutes)

Learn (25 minutes)

- Read Aloud *Tugboat* (15 minutes)
- Introduce Tugboats in New York Harbor (10 minutes)

Land (5 minutes)

Launch 5 minutes

Choose a big object, such as a reading table or a rolling bookcase, that students could move safely with assistance. Have students brainstorm different ways they could move the object across the classroom.

▶ **How could we move the reading table from the back of the room to the front of the room?**

After students share ways to move the object, ask them whether moving the object would be easy or difficult and to explain why. Encourage students to think about times when they saw people move something similar to the chosen object.

Sample student responses:

- *It would be hard to move because there's lots of stuff in the way.*
- *I think it would be difficult because it's heavy, and my parents sometimes need to help each other move heavy things.*

Agree that there are many reasons that it can be challenging to move big objects, and acknowledge that moving a big object in a small space can be especially difficult. Then tell students that an **object** is something that people can see or touch.

English Language Development

Students will encounter the term *object* throughout the module. Providing the Spanish cognate *objeto* may be useful. To reinforce the idea that an object is anything students can see or touch, consider generating a list of classroom objects.

After introducing *object* and other important terms, provide scaffolds for English learners as they use the terms when speaking, writing, and investigating. For more information, see the English Language Development section of the Implementation Guide.

Learn 25 minutes

Read Aloud *Tugboat* 15 minutes

Show students the cover of *Tugboat*. Allow students to briefly share with the class what they already know about tugboats. Explain that tugboats are important because they help move big, heavy ships through tight spaces.

Read the book aloud. After reading an important, unfamiliar word that students cannot define through context or morphological clues, pause to provide a familiar synonym or to define the word and use it in an example sentence. Then reread the sentence containing the word, and continue reading the text aloud. Important, unfamiliar words in *Tugboat* may include *dock*, *cargo ship*, *port*, *barge*, and *ocean liner*.

To prepare students for the second reading of the book, introduce the Phenomenon Question **What do tugboats do?** As students listen this time, have them use a nonverbal signal whenever they notice a tugboat helping a big ship. Pause every few pages, and ask students to whisper to a partner what they saw the tugboat do.

After the second reading, ask the following question.

▶ What did you learn about tugboats?

- *I learned that they move big ships.*
- *I found out that they help a lot of different ships.*

Teacher Note

Generally, boats are smaller than ships. However, students do not need to make this distinction and may refer to both vessels as boats or ships.

English Language Development

Students will encounter the terms *dock*, *port*, and *cargo* throughout the module. When each term appears in the text, point to the corresponding illustration. Explain that a dock is a place where ships can park that sticks out into the water. Tell students that a port is a place where ships go to pick up and drop off cargo and people. *Cargo* can refer to food, supplies, and other products. Providing the Spanish cognates for *port* (*puerto*) and *cargo* (*carga*) may also be useful.

Consider consulting the glossary at the end of *Tugboat* to find definitions for *barge*, *ocean liner*, and other terms in the text.

Teacher Note

The book shows the tugboat pulling several different vessels, but it depicts the tugboat pushing only the ocean liner. Consider drawing extra attention to this pushing interaction when reading page 16.

Differentiation

To support English learners during this discussion, consider sharing the following sentence frame: Before, I thought _____. Now I know _____. Model using this sentence frame so that students hear how they can use it to discuss how their thinking about tugboats has changed.

▶ How does the tugboat make the big ships move?

- *The tugboat pulls the big ships.*
- *I saw it pushing one of the ships.*

Build on student responses to summarize that the tugboat uses a push or pull every time it moves a big ship.

Check for Understanding

This task is a pre-assessment. Use students' responses to gauge their prior and developing knowledge of how pushes and pulls can cause objects to move as well as how observations can reveal patterns.

Elements Assessed	
PS2.A: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. CC.1: Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	
Evidence	**Next Steps**
After observing multiple instances of the tugboat moving ships, students recognize a pattern (CC.1): The tugboat always uses a push or a pull to move another vessel (PS2.A).	At this point, students do not need to fully understand how pushes and pulls can change an object's movement, and they do not need to independently identify the pattern. Make note of students who express misconceptions, and check in with those students again at the end of Concept 1.

Introduce Tugboats in New York Harbor 10 minutes

To introduce the anchor phenomenon—tugboats moving cargo ships through a harbor—show students the New York Harbor Knowledge Deck poster. Display the front of the poster, and ask students to share where they see tugboats in the harbor. Next, invite students to share what they wonder about the photograph.

Spotlight on Crosscutting Concepts

Throughout this module, students will look for patterns (CC.1), or repeated events, and will use them as evidence of cause and effect relationships (CC.2). Take this opportunity to note the patterns that students identify in how tugboats help move big ships.

Teacher Note

Provide context for the photograph on the poster by showing students the school's location and the location of New York Harbor on a map.

The New York Harbor Knowledge Deck cards first appear in Lesson 14.

For more information on how to use Knowledge Deck posters and cards, see the Implementation Guide.

English Language Development

Students will encounter the term *harbor* throughout the module. Tell students that a harbor is a big area of water that can have ports and docks where boats and ships can park. Explain that a harbor is like a parking lot in the water for boats and ships.

Before reading the text on the back of the poster, ask students to think silently about the following question.

▶ **How do you think tugboats help cargo ships in the harbor?**

Continue to display the photograph, and read aloud the text on the back of the poster. Then ask students to Think–Pair–Share about how tugboats help cargo ships in the harbor. Have a few students share their ideas with the class.

Sample student responses:

- *I think the tugboat helps by pulling the cargo ship so that the ship can get those boxes to the port.*
- *Maybe the tugboat can help move those boxes where they need to go.*

Confirm that tugboats play an important role in helping bring cargo ships to the port.

Content Area Connection: English

Consider either offering students guidelines for engaging in collaborative conversation or developing such guidelines as a class. When students work in pairs, encourage them to take turns speaking and to acknowledge the thoughts that their partners express (CCSS.ELA-Literacy.SL.K.1) (NGA Center, CCSSO 2010a).

Land 5 minutes

Return to the book *Tugboat*, and show students a few illustrations of tugboats at work. Highlight the different ways that tugboats help move big ships.

Explain that throughout this module students will explore how tugboats move cargo ships. Ask students to think about whether it is possible to study this phenomenon in the classroom, and confirm that because cargo ships are so big, the phenomenon will be difficult to explore. Then use the following questions to brainstorm possible ways to represent tugboats and cargo ships.

▶ **What objects in our classroom could we use to represent a tugboat and a cargo ship?**

- *We'd need to use something smaller for the tugboat and something bigger for the cargo ship.*
- *We could use an eraser for the tugboat and a tissue box for the cargo ship.*

▶ How could we use those objects to figure out how the tugboat moves the cargo ship?

- *We could move the eraser so that it pushes the tissue box around.*
- *We can push them around on the floor like they are boats in the water.*

Agree that students will need to use two objects of different sizes to represent the tugboat and the cargo ship. Tell students they will have the chance to create a model in the next lesson.

Content Area Connection: Mathematics

Consider using this lesson to address a Measurement and Data standard (CCSS.Math.Content.K.MD.A.1) (NGA Center, CCSSO 2010b) by providing comparisons students can relate to, such as the following: The longest cargo ships stretch the length of more than four football fields. Just one of these giant ships is as long as about 16 tugboats in a line (ZDF Enterprises, n.d.; *BC Shipping News 2012*).

Lesson 2

Objective: Construct an anchor model of a tugboat moving a cargo ship.

Agenda

Launch (5 minutes)

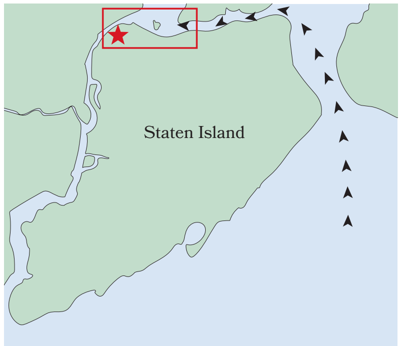
Learn (25 minutes)

- Model Tugboats in New York Harbor (10 minutes)
- Develop Anchor Model (15 minutes)

Land (5 minutes)

Launch 5 minutes

Introduce the map of Staten Island and New York Harbor (Lesson 2 Resource A).



Teacher Note

Before introducing the map of Staten Island and New York Harbor, consider showing students a map of the United States and pointing out the school's location. Then point out New York Harbor, and explain to students that they will see a map that shows that area up close.

Point out where cargo ships enter the harbor and the path they travel to get to their destination: a port on Staten Island. Briefly discuss the challenges these ships might face.

▸ Why might it be tough for cargo ships to move through these small spaces?

- *Maybe it's hard for the ships to turn.*
- *They might bump into land or other ships.*

Teacher Note

The arrows indicate the path cargo ships travel, the red star marks the port, and the red rectangle corresponds to the section of the harbor represented on the vinyl harbor map.

▶ **How is this problem similar to moving the reading table in our classroom?**

- *The reading table is also big and heavy and would be hard to push.*
- *We would also have to be careful turning the reading table if we moved it.*

Tell students that they will now create a model to explore how tugboats help move cargo ships through the harbor.

Learn 25 minutes

Model Tugboats in New York Harbor 10 minutes

With the map still displayed, explain to students that they will model part of a cargo ship's journey through the harbor. Point out the red rectangle on the map, and tell students that this is the area they will focus on.

Next, display the map model materials. Explain to students that they will use these materials to explore how tugboats help move cargo ships through the harbor and to the port. Show students where the port is on the vinyl harbor map by pointing to the brown area that has two red cranes. Then demonstrate how to use a chenille stem piece to connect and disconnect the wooden tugboat to the wooden cargo ship.

▶ **How can we use these materials to show how a tugboat moves a cargo ship to the port?**

- *We can make the little block the tugboat and the big block the cargo ship.*
- *We can try moving the tugboat to see if we can make it move the cargo ship.*
- *We can connect the blocks so that they move together.*

Teacher Note

Modify this question to refer to the classroom object students discussed in the Lesson 1 Launch.

Teacher Note

Students will use the map models again during the direction investigation in Lesson 11 as well as during the slowing down and stopping investigation in Lesson 14.

If the class does not have the vinyl harbor maps, use sketches of the harbor map instead. (See Lesson 2 Resource D.)

Place students in groups, and distribute a set of materials to each group. Explain to students that they should use the materials to show how a tugboat might move a cargo ship through the harbor. As students work, circulate and ask groups the following questions: How are you using the tugboat to move the cargo ship through the harbor? How does the model help you understand how tugboats move cargo ships?

Record at least one response from each group to refer to when developing the anchor model and the driving question board.

Develop Anchor Model 15 minutes

Bring the class back together to develop the anchor model. Explain that the class will add to the anchor model throughout the module as they learn about how tugboats move cargo ships through a harbor. Place the class vinyl harbor map on the floor where students can easily see it, and have groups share the different ways they used the tugboat to move the cargo ship. Invite students to use a set of wooden blocks on the map to demonstrate as they explain their ideas.

Sample student responses:

- *We pushed the cargo ship with the tugboat.*
- *We connected the tugboat to the ship, and we pulled the ship the whole way.*

Agree that the tugboat can move the cargo ship in different ways, and acknowledge that the models can help students figure out those different ways. Have the class decide how to arrange the cargo ship cutout and blue tugboat cutout (Lesson 2 Resource B) on the map to show one way a tugboat can help move a cargo ship. As students share ideas, have the rest of the class use nonverbal signals to show whether they agree.

Differentiation

Kindergarten students may need help staying focused as they model how the tugboat moves the cargo ship through the harbor. To keep students engaged while they are not actively moving the tugboat, ask them to observe how the students in their group move the cargo ship and to try to come up with a new way to move the ship.

Teacher Note

As students work, consider discussing ways to make the models more accurate. For example, students should keep both the cargo ship and the tugboat on the blue part of the map, which represents water. Students should also focus their attention on ways they can use the tugboat to move the cargo ship, instead of moving the cargo ship directly.

Teacher Note

The sample anchor model below shows the tugboat pulling the cargo ship from the front. Because tugboats can use both pushes and pulls to move cargo ships through a harbor, it is also acceptable for students to create an anchor model that shows the tugboat pushing the cargo ship from behind.

Tape the cargo ship cutout and blue tugboat cutout onto the map according to how students want to show the tugboat moving the cargo ship. Record a title for the anchor model, and write a sentence that summarizes what students have learned so far about tugboats moving cargo ships in a harbor.

Sample anchor model:

Tugboats Moving a Cargo Ship

A tugboat moves a cargo ship toward the port.

Hang the anchor model somewhere in the classroom where students can easily see it. Then ask them to share questions they have about the model, and record these questions on sticky notes.

Teacher Note

Position the cargo ship and blue tugboat on the right side of the map to leave room for updates to the anchor model.

If the class chooses to show the tugboat pulling the cargo ship, consider drawing the rope between the tugboat and the cargo ship on part of a sticky note and adding it to the model. For simplicity, the sticky note is not shown on the sample anchor model. Do not draw directly on the vinyl harbor map, as even dry erase marker may not come off.

Like the top of the map of Staten Island and New York Harbor, the top of the vinyl harbor map used throughout this module points north.

Teacher Note

As is convenient, use sentence strips, chart paper, or a whiteboard to post the title and explanation near the anchor model. *Tugboats* is plural in this sample title because a second tugboat will be added to the anchor model during the Lesson 12 update.

Teacher Note

Save questions recorded on sticky notes to add to the driving question board during the Lesson 3 Learn. Consider posting these sticky notes on relevant parts of the anchor model until then.

Land 5 minutes

Remind students that in the previous module they developed an anchor model to guide their learning about the weather at Mesa Verde. Then remind them that a model can help people understand how something works but that it is not the same as the real thing. Ask the questions below to help students recognize the similarities and differences between the anchor model and actual tugboats moving cargo ships in a harbor. ☑

▸ How is our model similar to a real tugboat moving a cargo ship in a harbor?

- *Our model shows a real place where tugboats help move cargo ships.*
- *Our tugboat is smaller than our cargo ship, just like real tugboats are smaller than real cargo ships.*

▸ How is our model different from a real tugboat moving a cargo ship in a harbor?

- *Our tugboat and cargo ship are much smaller than real tugboats and cargo ships.*
- *The boats in our model look like rectangles. Real tugboats and cargo ships aren't rectangles.*

Agree that there are many similarities between the model and real tugboats and cargo ships in a harbor and that there are also differences, some of which make it possible to use the model in the classroom.

☑ Check for Understanding

Students explored the similarities and differences between models and the phenomena they represent (SEP.2) in the previous module. Look for evidence that students understand

- how the harbor map anchor model is similar to the phenomenon and
- how the model is different from the phenomenon.

If students need support to identify similarities and differences between the model and the phenomenon, consider providing examples. Then invite students to share their own examples of similarities and differences.

Lesson 3

Objective: Ask questions about tugboats moving cargo ships.

Agenda

Launch (10 minutes)

Learn (20 minutes)

- Develop Essential Question (8 minutes)
- Build Driving Question Board (12 minutes)

Land (5 minutes)

Launch 10 minutes

Remind students that questions are important because asking questions helps scientists figure out what else they need to learn. Tell students that some questions are more useful than others.

To give the class a chance to evaluate possible questions, tell students to imagine that a team of scientists wants to learn how a tugboat moves a cargo ship to where it needs to go. Introduce the questions below, and display them to the class.

- What did the captain have for breakfast?
- What color is the tugboat?

Instruct students to share why these questions will not help the scientists learn how a tugboat moves a cargo ship.

Sample student responses:

- *It doesn't matter what the captain ate for breakfast. That won't help them figure out how the tugboat moves the cargo ship.*
- *I think a red tugboat could be just as strong as a blue tugboat.*

Explain to students that they will have the chance to share better questions later in the lesson, when they build a driving question board.

Learn 20 minutes

Develop Essential Question 8 minutes

Explain to students that they can think of questions to explore by using what they noticed while developing the anchor model, looking at the New York Harbor Knowledge Deck poster, and reading the book *Tugboat*. Provide students with the following sentence starter: I noticed …

Then prompt students to each think of a question that relates to what they noticed.

Model using this sentence starter with an example from the classroom.

- I noticed there are a lot of lunch bags in our bin. Why did so many students bring their own lunches today?

Then share a statement and a question such as the following.

- I noticed that in the last lesson we had different ideas about how to show a tugboat moving a cargo ship. Which of our models showed the ways that tugboats really move cargo ships?

Build on student responses to develop the Essential Question: **How do tugboats move cargo ships through a harbor?** Explain to students that they will use the same sentence starter to formulate related questions.

Build Driving Question Board 12 minutes

Ask students to use the sentence starter to share what they notice about how tugboats move cargo ships. Ensure that the anchor model, the Knowledge Deck poster, and the book *Tugboat* are all visible in the classroom. Remind students that they can look at these to help them think of questions, and explain that the best questions will help them reach their goal of answering the Essential Question.

Teacher Note

It is important to include students in the process of developing the Essential Question. If necessary, coach the class to use the question word *how* to start the question.

Differentiation

Kindergarten students may need help articulating their questions. Remind students to use question words such as *how*, *why*, and *what* to form questions. Consider displaying these question words and encouraging students to use the words as they share.

As students share, record their questions on individual sticky notes. Tell students they will use their questions to build a driving question board. Write the Essential Question across the top of a sheet of chart paper, and post the sticky notes with student questions below the Essential Question. Explain to students that they will return to this driving question board throughout the module as they try to answer their questions and ask new ones.

Keep the driving question board posted in a prominent place in the room so the class can easily revisit and update it throughout the module. Consider leaving space to post sample student work along the way.

Teacher Note

The driving question board will be developed throughout the module, and questions will eventually be divided into two columns, with unanswered questions in a separate area. At this point in the module, group all sticky notes in the Unanswered Questions area below the Essential Question. At the end of each concept, create a new column in the space below the Essential Question. Each column serves as a space to post student questions related to the learning in each concept. Questions that are not associated with the learning in a concept can remain posted in the Unanswered Questions area.

By the end of the module, many student questions will be posted in the relevant columns, while some will still be considered unanswered questions. Students address these remaining questions in the End-of-Module lessons to show that, in science, unanswered questions can inspire more learning.

To develop the driving question board with greater ease, consider writing the Essential Question, Unanswered Questions header, and Concept Focus Questions on sentence strips and affixing them to the driving question board with repositionable tape.

Teacher Note

Add the sticky notes that have the questions students asked after developing the anchor model in Lesson 2.

Teacher Note

Leave space at the bottom of the driving question board for a Related Phenomena section. The Related Phenomena section provides students with a chance to think about how other experiences in their lives connect with the anchor phenomenon. When students share experiences or prior knowledge related to pushes, pulls, and movement, record their responses on sticky notes, and post the notes in this section.

As students' understanding of the anchor phenomenon grows, they can reflect on these related phenomena to practice applying their new knowledge to the world around them.

For a sample driving question board, see the Land section of this lesson.

Check for Understanding

As students share their questions, listen for evidence that they connect their questions to their observations.

Elements Assessed	
SEP.1: Ask questions based on observations to find more information about the natural and/or designed world(s). PS2.A: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	
Evidence	**Next Steps**
Students use what they have noticed to ask questions (SEP.1) about how tugboats help move cargo ships through a harbor (PS2.A).	If students share questions that are unrelated to the anchor phenomenon, ask them first to share something they noticed. If necessary, guide students to make observations that could lead to a meaningful question about how tugboats move cargo ships through a harbor. Then help students use a question word, such as *how*, *why*, or *what*, to frame their question.

Land

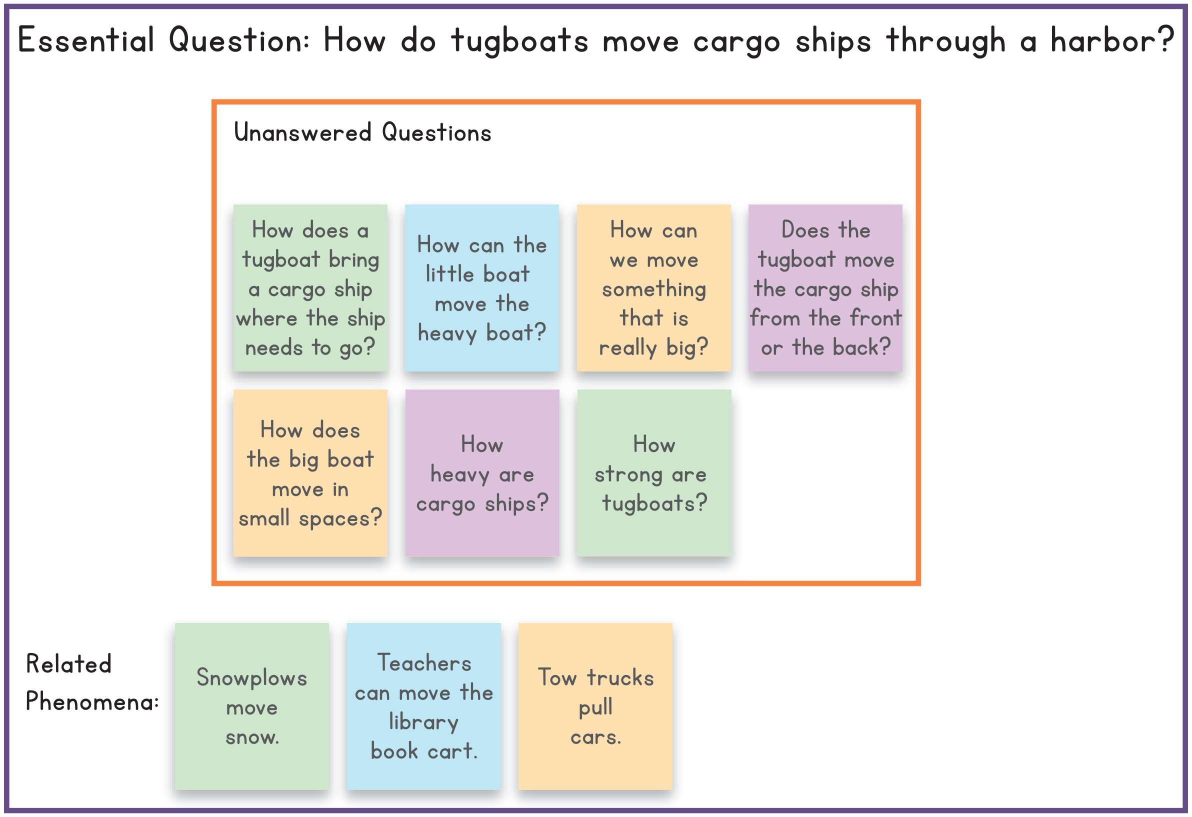
5 minutes

Tell students that scientists plan investigations to help find answers to their questions. Explain to students that they can investigate how tugboats help move cargo ships not only by modeling a tugboat, a cargo ship, and a harbor but also by exploring other examples of using pushes or pulls to move an object.

▸ What are some other examples of something or someone moving an object with a push or pull?

Add student ideas to the bottom of the driving question board under Related Phenomena.

Sample driving question board:



Ask students to share ideas for objects that they could use to explore movement. Explain to students that they will have the chance to start searching for answers to their questions in the next lesson.

Optional Homework

Students pay close attention to objects that move and look for clues that might help them answer their questions.

Lessons 4–6
Making Objects Start to Move

Prepare

In this lesson set, students explore what causes objects to move, and they develop an understanding that when an object starts moving, it does so because of a push or a pull (PS2.A). In Lesson 4, students use a set of toys to explore ways to start movement. Students find that they can sort their actions into two categories: pushes and pulls. In Lesson 5, students identify pushes and pulls in other contexts and record their observations of those actions (SEP.4). By testing their thinking in a variety of situations, students recognize the pattern that pushes and pulls cause objects to move (CC.1). Lesson 6 introduces students to a water model that helps them make sense of their learning in the context of the anchor phenomenon.

Concept 1: Starting Movement

Focus Question

What causes objects to start moving?

Phenomenon Question

How do tugboats make cargo ships start to move?

Student Learning

Knowledge Statement

Pushes and pulls can cause objects to start moving.

Objectives

- Lesson 4: Categorize actions as pushes or pulls.
- Lesson 5: Record and reflect on observations of pushes and pulls.
- Lesson 6: Apply new understanding of pushes and pulls to the anchor phenomenon.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Developing)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.4: Analyzing and Interpreting Data ▪ Record information (observations, thoughts, and ideas). *Connections to Nature of Science* Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena ▪ Scientists search for cause and effect relationships to explain natural events.	PS2.A: Forces and Motion ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	CC.1: Patterns ▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. CC.2: Cause and Effect ▪ Events have causes that generate observable patterns. *Connections to Nature of Science* Science Is a Way of Knowing ▪ Scientific knowledge informs us about the world.

Materials

		Lesson 4	Lesson 5	Lesson 6
Student	Movement exploration materials (1 set per group): table tennis ball (1), chart paper (1 sheet), plastic puck (1), sticky hand (1), toy car (1)	●		
	Sticky note (1 per student pair)		●	
	Science Logbook (Lesson 5 Activity Guide)		●	
Teacher	Push and pull chart: chart paper (1 sheet), dry erase marker (1), push and pull chart header symbols (1 of each), tape, toy icon cards (2 sets)	●	●	
	Toy car (1)	●		
	Toy Stroller Photograph (Lesson 5 Resource A)		●	
	Toy stroller icon card (1)		●	
	Push cutouts and pull cutouts (1 set)		●	●
	Painter's tape		●	●
	Tugboat (Garland 2014)			●
	Water model: #10 $\frac{3}{4}$″ pan head screw (1), $\frac{3}{4}$″ vinyl-coated screw-in hooks (2), 5 cm × 15 cm × 2 cm wooden block (1), 12″ chenille stem (1), 34″ × 16″ × 6″ or larger plastic bin (1), paper towels, plastic toy tugboat with holes atop front and back ends (1), access to water			●
Preparation	Prepare push and pull chart header symbols. (See Lesson 4 Resource A.)	●		
	Prepare toy icon cards. (See Lesson 4 Resource B.)	●		
	Prepare toy stroller icon card. (See Lesson 5 Resource B.)		●	
	Cue "The Royal Ballet Performance of *Alice's Adventures in Wonderland*" (Royal Opera House 2015) video: http://phdsci.link/1576.		●	
	Prepare push cutouts and pull cutouts. (See Lesson 5 Resource C.)		●	
	Prepare water model. (See Lesson 6 Resource.)			●

Agenda

Launch (5 minutes)

Learn (25 minutes)

- Explore Movement (10 minutes)
- Sort Actions (15 minutes)

Land (5 minutes)

Lesson 4

Objective: Categorize actions as pushes or pulls.

Launch 5 minutes

Teacher Note

Throughout this module, students may notice examples of movement that they struggle to explain by applying their knowledge of pushes and pulls (e.g., how people start to walk, how vehicles start to move forward, why objects fall to the ground). In Lesson 5, the class summarizes that all objects need a push or pull to start moving. This statement is true even when the push or pull is difficult to detect. For example, when a person starts to walk, the person's feet push backward on the ground, and friction between the two surfaces pushes the person forward; when a vehicle starts to move, its tires push backward on the ground, and friction between the two surfaces pushes the vehicle forward; and Earth's gravity pulls all objects on or near its surface downward, causing objects in midair to fall. Students will learn about these more abstract examples in later levels. In the meantime, support students' curiosity by offering age-appropriate explanations for their questions, and add their questions to the driving question board.

Show students the set of toys (table tennis ball, plastic puck, sticky hand, and toy car) that they will use to explore pushes and pulls. Invite students to share their experiences playing with toys like these.

Sample student responses:

- *I like pushing toy cars around a track.*
- *I've used a sticky hand to try to pick stuff up.*
- *I bounce balls, throw them, and roll them around.*

Highlight student responses that describe different ways to move the toys.

- ▶ How could we use these toys to learn about how tugboats help move cargo ships?
  - *We could play with the toys and look at how they move.*
  - *When we're moving the toys, we can pretend that we are tugboats and they are cargo ships.*

- ▶ Do these toys move the same way as tugboats and cargo ships? Why do you think that?
  - *No, they don't move the same way. Boats and ships move in water. These toys move on the floor or on tables.*
  - *I think the puck and the car move like the boats because they all move in a straight line. The ball can move like that too, but sometimes it moves differently because it bounces.*

Agree that there are similarities and differences between how the toys move and how tugboats and cargo ships move. Remind students that scientists often try to figure out how something works by exploring how a similar object works.

Introduce the Phenomenon Question **How do tugboats make cargo ships start to move?** Explain to students that in this lesson they will explore the different ways they can make these toys start to move so that they can figure out how tugboats help move cargo ships.

Learn 25 minutes

Explore Movement 10 minutes

Place students in groups, and distribute a set of toys and a sheet of chart paper to each group.

Safety Note

This activity poses potential hazards. Explain to students that they need to handle the toys safely. Review these safety guidelines with students to minimize the risks:

- Do not throw or bounce the toys.
- Keep the toys on the sheet of paper at all times.
- Follow classroom rules for handling and sharing materials during the exploration.

Invite students to explore the different ways that they can make the toys move across the paper. Guide students with questions such as these:

- What are some other ways you can move this toy across the paper?
- How could you use one toy to move another toy?
- How does moving these toys remind you of a tugboat moving a cargo ship?

Sort Actions 15 minutes

Collect the toys, and invite students to share how they made the toys move across the paper.

Sample student responses:

- *We pushed the ball with our hands.*
- *We pulled the sticky hand across the paper.*

As students share, have the rest of the class listen carefully and use their hands to act out each response. After the class acts out a few responses, point out that many students used their hands in similar ways to make the toys move.

Create a push and pull chart. Tape the chart header symbols (Lesson 4 Resource A) to a sheet of chart paper, and draw lines to create a two-column chart. Label one column Push and the other column Pull.

Teacher Note

To prevent the sticky hands from lifting or moving the sheets of chart paper, encourage students to hold their paper down while they pull on the sticky hand.

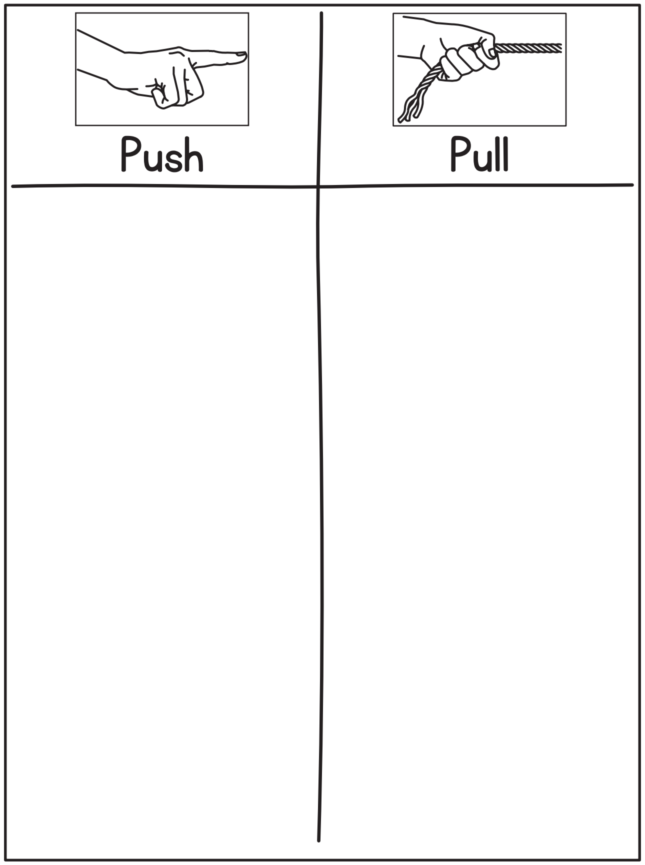
Teacher Note

When sharing, some students may focus on how the object moved (e.g., by rolling, by sliding). In these situations, encourage students to share what they did to cause the toy to move that way (e.g., push).

Teacher Note

Keep the push and pull chart on display so that students can add a toy stroller card to it in the next lesson and so that they can refer to the chart easily throughout the module.

Sample class chart:



Then build on common themes from the discussion to explain that a **push** can move an object away and a **pull** can move an object closer.

English Language Development

In this module, students will see and hear the terms *push* and *pull* used as both nouns and verbs. Introduce both terms explicitly by using strategies such as the following:

- Provide student-friendly examples of pushes and pulls, such as pushing a friend on a swing or pulling a balloon on a string.
- Invite students to think of other examples of pushing and pulling.

Ask students to act out the terms *push* and *pull*, and as a class, decide on a movement to represent each term. For example, when students say "push," they can move open palms away from their body in a pushing movement. When they say "pull," they can start with closed fists extended out in front of their body and then move their hands toward their body in a pulling movement.

Explain to students that they will describe each way they moved a toy as either a push or a pull. Redistribute two sets of toys so that each group receives at least one of the eight toys. Ask each group to demonstrate to the class one way they were able to move their toy.

After each group demonstrates an action, ask the class whether that action is a push or a pull. As students share their ideas, invite the rest of the class to use nonverbal signals to show whether they agree or disagree. Then tape a matching toy icon card (Lesson 4 Resource B) to the chart in the agreed-upon column. Draw a pushing or pulling hand on each card to show students how they made the toy move.

Teacher Note

If students focus exclusively on pushes (or pulls), challenge them to share actions that fit in the other column. For example, guide the second group with each toy to demonstrate a way they can move the toy that is different from the way the first group moved it. Allow both groups with the sticky hands to demonstrate pulls because the sticky hand does not move well with a push.

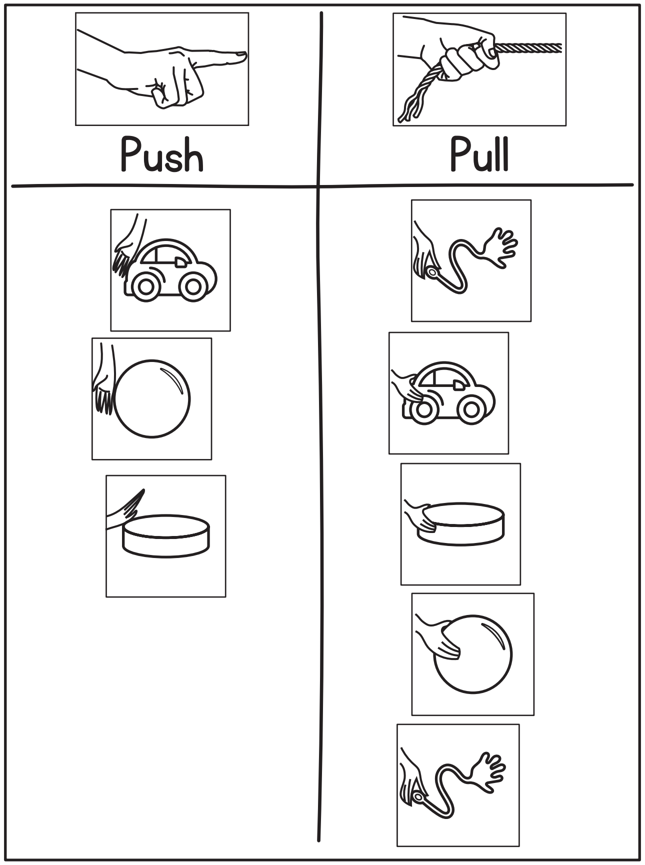
Teacher Note

If groups have more than one toy, instruct them to carry out their demonstrations one at a time.

Content Area Connection: English

When students act out, discuss, and compare different pushes and pulls, they explore word relationships and nuances in word meanings (CCSS.ELA-Literacy.L.K.5). To expand students' vocabulary and conceptual understanding, consider sharing words that describe pushing and pulling actions (e.g., *tap*, *nudge*, *tow*, *tug*).

Sample class chart:



To help students identify a pattern, have them reflect on the actions they used to make the toys start to move. ✓

▶ What did we do to make each toy start to move?

- *We either pushed it or pulled it.*

✓ **Check for Understanding**

Listen for students to recognize that a push or a pull always started each toy's movement (CC.1). In the discussion in this lesson's Land, students will use this pattern as evidence of a cause and effect relationship.

Agree that each time students made a toy move across the paper, they pushed or pulled it. Explain that when we notice something that happens the same way many times, we can describe the repeating event as a pattern. Then remind students that they can use a pattern to predict what is likely to happen.

Land 5 minutes

Place the toy car in a visible spot, and ask students to briefly Think–Pair–Share in response to the following question.

▶ What do you think will happen if I push this toy car?

- *It will start to move.*
- *I think it will move away from you.*

Push the toy car, and tell students that they used the pattern they have observed to predict when an object will start moving. Explain that this pattern is a clue that suggests students have found a cause and effect relationship.

Tell students that an effect is something that happens because of something else. Point out that when students pushed the car, the car moved. Explain that the cause was the push and the effect was that the car moved.

Optional Homework

Outside of the classroom, students pay attention to pushes and pulls that cause objects to start moving.

Teacher Note

Remind students that they found a pattern in the previous module when they observed how the temperature goes up and down throughout each day.

English Language Development

Students will encounter the terms *predict* and *prediction* throughout the module. Providing the Spanish cognates for *predict* (*predecir*) and *prediction* (*predicción*) may be helpful. Explain that a prediction is what we think might happen. To further illustrate the meaning of these terms, consider having students predict what the weather will be like later in the day.

English Language Development

Students will encounter the terms *cause* and *effect* throughout the module. Introduce the term *cause* in its noun and verb forms. Providing the Spanish cognates for the noun *cause* (*causa*), the verb *cause* (*causar*), and *effect* (*efecto*) may be useful. Explain that a cause is why something happened and an effect is what happened. Generate examples of cause and effect situations students may be familiar with, such as the following:

- I brushed my teeth (cause), so now my teeth are clean (effect).
- I drank all my milk (cause), so my milk carton is empty (effect).

Spotlight on Crosscutting Concepts

If necessary, repeat the toy car demonstration, and work with students to emphasize that patterns can be evidence of a cause and effect relationship. Support students' understanding that they always need to use a push or a pull to cause an object to start moving.

Lesson 5

Objective: Record and reflect on observations of pushes and pulls.

Agenda

Launch (5 minutes)

Learn (23 minutes)

- Draw Pushes and Pulls (15 minutes)
- Create Anchor Chart (8 minutes)

Land (7 minutes)

Launch 5 minutes

Show students the toy stroller photograph (Lesson 5 Resource A).

Ask students to use a nonverbal signal to show whether they have ever seen a toy stroller. Have students Think–Pair–Share to brainstorm the different ways they could get the stroller to move.

▶ How could you make this stroller start to move?

- *We could push it.*
- *We might also be able to pull it.*

Invite a few pairs to share ideas. As students share, direct their attention to the push and pull chart from the previous lesson. Ask students where they would place their actions on the chart. Choose one example, and place a toy stroller icon card (Lesson 5 Resource B) in the appropriate column. Draw a hand on the card to show the push or pull.

Extension

Consider preparing an additional toy stroller icon card. If time allows, choose a second student example that involves whichever action (push or pull) is not already on the chart, and repeat this exercise with the second card.

If students suggest examples of only pushes or only pulls, encourage them to consider whether they could also move the toy stroller with the other action.

Learn 23 minutes

Draw Pushes and Pulls 15 minutes

Point out that students have started to look at the world around them as scientists do, searching for pushes and pulls and trying to explain what they see. Explain that scientists also record what they observe to figure out how the world around them works.

Place students in pairs, and distribute one sticky note to each pair. Tell students to look around the classroom for objects they could move with a push or a pull and to work with their partners to choose one of these objects. Instruct one student from each pair to place a sticky note on the object they have chosen.

Safety Note

Pushing or pulling certain classroom objects may not be safe. Make sure students understand that they should not push or pull the objects they choose. As an additional safety measure, consider restricting students to a play area in the classroom, away from heavy objects students could potentially try to move.

Have students return to their seats, and invite a few students to explain how they could use pushes or pulls to move their objects.

Sample student responses:

- *We could push the door to open it.*
- *We could pull my backpack to get it out of my cubby.*

After students share, choose one object that they selected. Encourage students to watch closely to see how the object moves because of a push or a pull. Then demonstrate pushing or pulling the object.

Tell students that they will now record what they just observed. Ask students to draw their observations in their Science Logbooks (Lesson 5 Activity Guide). Then use the following questions to elicit ideas about the relationship between a push or a pull and an object's movement.

▶ What caused the _____ to start moving?

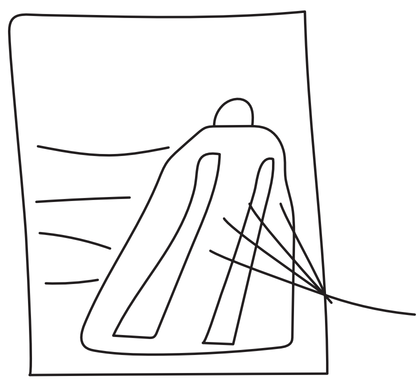
▶ How can you show in your drawing how I made the _____ move?

▶ Did you observe a push, or did you observe a pull? How do you know?

- *I observed a pull. I know because the backpack moved closer to you.*
- *I know I observed a pull because you made a fist when you grabbed the backpack. Then you moved your hand toward your body.*

When students finish drawing the action they observed, have them identify the action as either a push or a pull by circling the correct symbol and word in their Science Logbooks (Lesson 5 Activity Guide).

Sample student drawing:



Differentiation

Students will draw a push or a pull interaction with the chosen object. Consider choosing an object that students can represent with a simple drawing; if necessary, demonstrate how to draw this object. For example, students may draw a rectangle to represent a door.

To help students record their observations, it may also help to demonstrate a sustained push or pull on the object.

Check for Understanding

Students record their observations of how the object started moving, identify the action as either a push or a pull, and orally demonstrate an understanding of what caused the object to move.

Elements Assessed	
SEP.4: Record information (observations, thoughts, and ideas). PS2.A: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. CC.2: Events have causes that generate observable patterns.	
Evidence	**Next Steps**
The observations that students recorded (SEP.4) include both the object and the push or pull that made the object start to move (PS2.A).	If students do not represent both the object and the push or pull, repeat the action, and encourage students to draw the object and a hand pushing or pulling the object.
Students correctly identify the cause of the movement as either a push or a pull (CC.2).	If students select the incorrect action, refer to the push and pull chart from the previous lesson. Ask students to think about which group of actions this one is more similar to: the actions in the Push column or those in the Pull column.

Create Anchor Chart 8 minutes

Work with students to summarize the cause and effect relationship between a push or a pull and an object moving.

▶ In all the examples we observed, how did we get an object to start moving?

- *We made the toys move with a push or a pull.*
- *We saw that we need to push or pull objects in our classroom to make them move.*

▶ How can we cause an object to move?

- *We have to push or pull an object to cause it to move.*

Summarize student responses to conclude that objects need a push or a pull to start moving. Then explain that sometimes pushes or pulls may not be enough to move an object. To clarify this point, ask students to Think–Pair–Share about objects they can push or pull on but cannot move.

Sample student responses:

- *I can't move my brother. He's too big.*
- *If I push on the wall, it doesn't move.*

Confirm that sometimes pushes and pulls can cause objects to start moving and sometimes they cannot. Tell students that to keep track of their learning throughout the module, the class will develop an anchor chart. Summarize students' new learning on a sentence strip, and place the sentence strip on the anchor chart.

Sample anchor chart:

Pushes and Pulls
Starting Movement • Pushes and pulls can cause objects to start moving.

Land 7 minutes

Introduce the ballet video (Royal Opera House 2015) (http://phdsci.link/1576). Tell students that as they watch, they should use the push and pull movements that the class agreed upon in Lesson 4 to indicate when they notice a push or a pull happening. Play the first 40 seconds of the video.

Teacher Note

At this point, focus on supporting students' understanding that pushes and pulls can, but do not always, move objects. In later levels, students will learn more about how mass, friction, force, and acceleration relate.

Teacher Note

Kindergarten students may conflate size with weight and mass. Accept this language, and consider rephrasing their responses with words like *heavy* (or *light*) in place of *big* (or *small*).

Teacher Note

For more information on how to create the anchor chart, see the Anchor Visuals section of the Implementation Guide.

Next, restart the clip, and pause during one of the push or pull interactions that students noticed. Work together as a class to decide where on the screen to affix either a push cutout or a pull cutout (Lesson 5 Resource C) with painter's tape. Play the video through the first 2 minutes, stopping at one or two other points to place additional cutouts on the screen.

▶ In the video, what happened because of pushes and pulls?

- *When the man pulled the woman, she moved toward him.*
- *The dancers move across the stage because of pushes and pulls.*

Summarize that pushes and pulls happen everywhere, and tell students that learning about these interactions can reveal a lot about the world. Tell students that in the next lesson they will use their knowledge of pushes and pulls to update the anchor model.

Teacher Note

If students have difficulty seeing the pushes and pulls between the ballet dancers, consider playing the video at half speed during the second viewing.

Replaying the video at the following times may help highlight push and pull interactions:

- When the knave moves Alice across the stage (0:13–0:16)
- When the knave and Alice pull on each other (0:35–0:36)
- When the knave pulls Alice's hand as she slides across the stage (1:01)
- When the knave pushes and pulls Alice (1:40–1:49)

Lesson 6

Objective: Apply new understanding of pushes and pulls to the anchor phenomenon.

Launch 5 minutes

Display pages 14 through 19 of *Tugboat*, and ask students to look for pushes and pulls in the illustrations. Have volunteers use painter's tape to affix push cutouts and pull cutouts (Lesson 5 Resource C) onto the illustrations. Tell the remaining students to use the class's push and pull movements from Lesson 4 to show whether they agree.

Next, remind students of the exploration in which they moved different toys across a sheet of chart paper.

▶ **When you moved the toys, how was that similar to the tugboat moving ships in the book?**

- *Our pushes and pulls were like the pushes and the pulls in the book.*
- *The tugboats push and pull the ships, just like we pushed and pulled the toys.*

Acknowledge that the tugboat moves the ships with pushes and pulls just as the class moved the toys with pushes and pulls. Point out that one important difference between how students moved the toys and how real tugboats help move cargo ships is that tugboats work in water. Explain that it is important to find out whether students' ideas about pushes and pulls hold true in water.

Agenda

Launch (5 minutes)

Learn (28 minutes)

- Introduce Water Model (18 minutes)
- Update Anchor Model (10 minutes)

Land (2 minutes)

Learn 28 minutes

Introduce Water Model 18 minutes

Place the water model in an area that is clearly visible to all students. Show students the model materials, and tell students that the plastic boat represents a tugboat and the wooden block represents a cargo ship.

Safety Note

The water model, which students will use throughout this module, poses potential hazards. Review these safety guidelines with students to minimize the risks:

- Move the model tugboat and cargo ship carefully in the water to avoid splashing water out of the bin.
- If water spills, tell an adult right away.
- Do not drink the water.

▶ How is this model like our anchor model?

- *They both have a tugboat and a cargo ship.*
- *Both models can show how the tugboat moves the ship.*

▶ How is this model different from our anchor model?

- *The boats are in the water instead of on the map.*
- *The boats look a little different.*

Direct students' attention to the anchor chart, and reread the summary of students' learning from the previous lesson: Pushes and pulls can cause objects to start moving.

▶ How could we use this model to test our ideas about pushes and pulls in the water?

- *We could use the tugboat to push the block.*
- *We could tie the tugboat to the cargo ship and pull the ship.*

Demonstrate the different interactions between the tugboat and cargo ship as students suggest them.

Differentiation

To support students with visual impairments, consider introducing the water model to one group of students at a time.

Guide students to think about how this model could help them better understand the Phenomenon Question **How do tugboats make cargo ships start to move?**

▶ **In our water model, how can the tugboat get the cargo ship to start moving?**

- *The tugboat has to push or pull the cargo ship.*

Explain to students that they can use what they learned about pushes and pulls from the water model to update the anchor model.

Update Anchor Model 10 minutes

Direct students' attention to the anchor model, and ask students how they could use a push cutout or a pull cutout (Lesson 5 Resource C) to update the model. Use student input to determine where on the anchor model to tape the cutout so that it marks where the push or pull occurs. Revise the explanation below the model to specify how the tugboat moves the cargo ship.

Check for Understanding

Listen for students to identify that the tugboat can use a push or a pull to cause the cargo ship to start moving (CC.2).

Teacher Note

For the rest of the module, consider keeping the water model in a designated space where students can safely explore how the plastic tugboat and wooden block move in water.

Extension

If time allows, supervise students as they take turns experimenting with the water model.

Sample anchor model:

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

Land 2 minutes

Revisit the Phenomenon Question **How do tugboats make cargo ships start to move?** Invite students to share how they would answer the question.

Sample student responses:

- *Tugboats can pull cargo ships to make them start moving.*
- *Tugboats can also get cargo ships to start moving by pushing them.*

Summarize student responses by stating that tugboats can use pushes and pulls to make cargo ships start moving. Tell students that they will further explore pushes and pulls in the next lesson.

Lessons 7–8
Push and Pull Strength

Prepare

In Lessons 7 and 8, students explore how stronger and weaker pushes and pulls can affect an object's movement (PS2.A) to build on their knowledge of how tugboats help move cargo ships. In Lesson 7, students plan and carry out an investigation (SEP.3) to determine that a stronger push makes an object move faster, and a weaker push makes an object move slower (CC.3). In Lesson 8, students revisit the water model to explore how pushes and pulls of different strengths affect the movement of an object in water. Students then use their new understanding to update the anchor model.

Concept 1: Starting Movement

Focus Question

What causes objects to start moving?

Phenomenon Question

How can a tugboat make a cargo ship move fast or slow?

Student Learning

Knowledge Statement

Stronger pushes and pulls cause objects to move faster than weaker pushes and pulls.

Objectives

- Lesson 7: Investigate stronger and weaker pushes.
- Lesson 8: Apply knowledge of stronger and weaker pushes and pulls to the anchor phenomenon.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Developing)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. ▪ With guidance, plan and conduct an investigation in collaboration with peers. SEP.4: Analyzing and Interpreting Data ▪ Use and share pictures, drawings, and/or writings of observations.	PS2.A: Forces and Motion ▪ Pushes and pulls can have different strengths and directions. ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS3.C: Relationship Between Energy and Forces ▪ A bigger push or pull makes things speed up or slow down more quickly.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns. CC.3: Scale, Proportion, and Quantity ▪ Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).

Materials

		Lesson 7	Lesson 8
Student	Faster and slower pushes investigation (1 set per student pair): table tennis ball (1), craft sticks (2)	●	
	Science Logbook (Lesson 7 Activity Guide)	●	
	Stronger and weaker push cutouts (1 of each)	●	
	Glue stick (1)	●	
Teacher	Stronger and weaker push cutouts (1 of each in Lesson 7, 1 weaker push cutout in Lesson 8 if the anchor model shows the tugboat pushing the cargo ship)	●	●
	Water model materials: prepared plastic bin from Lesson 6 (1), prepared chenille stem from Lesson 6 (1), paper towels, prepared plastic toy tugboat from Lesson 6 (1), prepared wooden block cargo ship from Lesson 6 (1)		●
	Stronger and weaker pull cutouts (1 of each)		●
Preparation	Cue video of a tugboat pushing a cargo ship: http://phdsci.link/1577.	●	●
	Prepare stronger and weaker push and pull cutouts. (See Lesson 7 Resource.)	●	

Lesson 7

Objective: Investigate stronger and weaker pushes.

Agenda

Launch (7 minutes)

Learn (25 minutes)

- Investigate Pushes (15 minutes)
- Compare Results (10 minutes)

Land (3 minutes)

Launch 7 minutes

Play the video of a tugboat pushing a cargo ship (http://phdsci.link/1577). Explain that the video shows a part of New York Harbor that is close to the port that appears on the anchor model.

Use the questions below to drive a discussion about the cargo ship's speed. After each student response, ask the rest of the class to give a nonverbal signal, such as a thumbs-up or thumbs-down, to indicate whether they agree.

▸ Do you think the cargo ship is moving fast or slow? How can you tell?

- *I think it's moving kind of slow because it looks like it's not going fast.*
- *I think it's slow because I see cars driving on the bridge, and they are faster.*

▸ What could be a reason that the tugboat is moving the cargo ship slowly?

- *I think the tugboat moves the cargo ship slowly so the cargo ship doesn't crash.*
- *Maybe the tugboat can't make it move faster.*

Summarize student responses, and point out that slower speeds are often safer. Explain that **speed** describes how fast or slow an object is moving.

Teacher Note

Students may need help finding evidence that the cargo ship is moving slowly. Consider pointing out the cars driving across the bridge so that students can compare the faster cars to the slower ship.

Teacher Note

In some instances, this module describes objects as moving "fast" or "slow" (instead of "quickly" or "slowly") for the sake of Kindergarten readability and comprehension.

Differentiation

To help students imagine the challenges of moving something as big as a cargo ship, remind students of the big classroom object they discussed moving in the Lesson 1 Launch. Have students consider whether it would be safer to move this object quickly or slowly through the classroom.

English Language Development

Introduce the term *speed* explicitly. Students can focus on using the words *faster* and *slower*, relative terms that describe speed. Consider reminding students of the relative scale they learned about in the previous module when they described temperature as warmer and cooler.

Learn 25 minutes

Investigate Pushes 15 minutes

Remind students that scientists often plan and carry out investigations. Explain that when scientists carry out an investigation, they follow steps to try to find answers to their questions.

Then introduce the Phenomenon Question **How can a tugboat make a cargo ship move fast or slow?** Tell students they will conduct an investigation to figure out how they can make an object move at different speeds.

Teacher Note

In this lesson set, students investigate how to make a stationary object (a table tennis ball) reach faster and slower speeds. Students observe the direct relationship between force and acceleration by comparing the effects of stronger and weaker pushes. In this case, the greater acceleration that results from a stronger push translates to a greater speed, and speed is easier for students to observe than acceleration. As such, it is reasonable for students to focus their attention on how fast the ball moves after each push. In later levels, students will use the terms *force* and *acceleration* to describe similar interactions, and they will distinguish between acceleration, speed, and velocity.

Place students in pairs. Show the class a set of investigation materials (a table tennis ball and craft sticks). Explain that pairs will practice using the craft sticks to roll the ball back and forth, and then pairs will try to make the ball roll at different speeds: faster and slower. While reviewing the plan with the class, list each step on a sheet of chart paper.

English Language Development

Students will encounter the terms *investigate* and *investigation* throughout the module. Providing the Spanish cognates for *investigate* (*investigar*) and *investigation* (*investigación*) may be helpful.

Teacher Note

To engage students in the planning process, consider letting the class decide on the order of the final steps. They can first try to make the ball move faster and then try to make it move slower, or vice versa.

English Language Development

To reinforce the steps of the investigation and to make the plan as accessible as possible, consider adding a sketch next to each instruction.

Sample investigation plan:

Investigation Plan
1. *Sit across from your partner.*
2. *Push the ball to your partner.*
3. *Try to make the ball move faster.*
4. *Try to make the ball move slower.*

Have students consider the purpose of the plan.

▶ Why is it important to plan our investigations?

- *Planning helps us know what we're doing.*
- *If we don't follow a plan, then we might get hurt.*

Explain to students that they will follow the steps and then record their observations in their Science Logbooks (Lesson 7 Activity Guide) to show the speed of the ball. Seat students in each pair across from one another, either at desks or on the floor. Distribute a set of materials to each pair.

Safety Note

This activity poses potential hazards. Review these safety guidelines with students to minimize the risks:

- Do not throw or bounce the ball.
- Keep the ball on the desk or floor at all times.

Coach students through the remaining steps of the investigation plan. After students finish the investigation, demonstrate on the board how adding movement lines to a drawing of an object can indicate the object's speed. Show students that drawing a lot of longer lines next to an object makes the object look as if it is moving faster, whereas drawing a few shorter lines next to an object makes it look as if it is moving slower. Then instruct students to complete the first two prompts in their Science Logbooks (Lesson 7 Activity Guide) by drawing movement lines in the two boxes, to the left of the ball illustrations.

Teacher Note

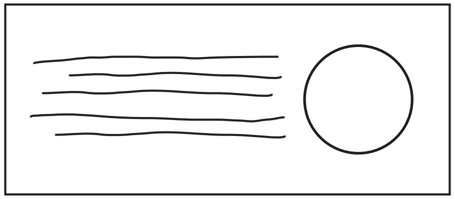
Following the same investigation plan ensures that the class can fairly compare the results from each group. A shared plan also allows students to collectively interpret and discuss class findings.

Use responses to assess students' knowledge of why scientists plan their investigations. After students complete the investigation, they will reflect on the importance of following a common set of steps.

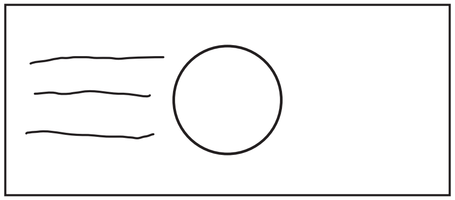
Spotlight on Science and Engineering Practices

This investigation is the first one that students conduct collaboratively (SEP.3). During the investigation, guide students to focus on the steps they must follow to succeed. Subsequent lessons in this module give students the opportunity to provide increasing input when planning and conducting investigations.

Sample student response for ball moving faster:



Sample student response for ball moving slower:



Compare Results 10 minutes

Collect the materials, and bring the class back together. Then ask students how they could record the pushes they used to make the ball move faster and slower.

If students need prompting, remind them about the push and pull cutouts they used in previous lessons.

▸ Should we use the same picture for both pushes? Why or why not?

- *Yes. They're both a push, so we can use a push picture for both.*
- *No. We shouldn't because I pushed really hard to make the ball move fast, but I only gave the ball a little push to make it move slow.*

Highlight the words students use to describe the different pushes they applied. Then point out that students used pushes of different strengths. Explain that **strength** describes how strong or weak something is.

Content Area Connection: Mathematics

When students describe the movement of the ball as faster in one situation and slower in another, they are developing the ability to compare measurable attributes (CCSS.Math.Content.K.MD.A.2). Consider pointing out to students that people can use tools to measure an object's speed.

English Language Development

Introduce the term *strength* explicitly. Students can focus on using the words *stronger* and *weaker*, relative terms that describe strength. Explain that a stronger push is a bigger push and a weaker push is a smaller push. Consider having students use the following sentence frames for support as they connect push strength with ball speed:

- When we used a weaker push, the ball moved _____.
- When we used a stronger push, the ball moved _____.

Show the class a pair of stronger and weaker push cutouts (Lesson 7 Resource).

Teacher Note

Save these cutouts for potential use when updating the anchor model in future lessons.

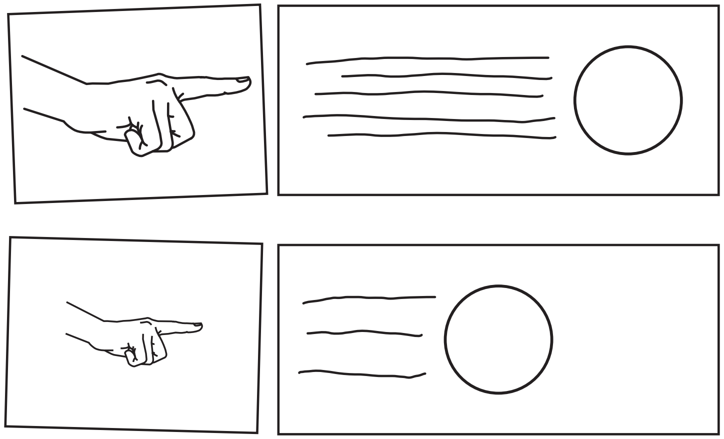
Ask students how these cutouts could help them show the different pushes they used. Agree that students can use the cutout with the larger hand to show a stronger push and the cutout with the smaller hand to show a weaker push.

Distribute a pair of stronger and weaker push cutouts (Lesson 7 Resource) to each student. Then guide students to decide which cutout they should glue to the left of each box in their Science Logbooks (Lesson 7 Activity Guide) so that the push strength on the left corresponds with the ball's speed on the right.

Teacher Note

To further distinguish between the stronger and weaker push and pull cutouts, classes may elect to use a color-coding or shading system. For example, students may color the smaller hands on the weaker cutouts a light shade of blue and the larger hands on the stronger cutouts a dark shade of blue.

Sample student response:



After students finish gluing the cutouts into their Science Logbooks, invite pairs to share their observations with the class. ☑

▸ What happened when you used a weaker push?
▸ What happened when you used a stronger push?

Point out the similarities between students' results. Then confirm that a stronger push caused the ball to move faster and a weaker push caused the ball to move slower.

Check for Understanding

Listen for students to make connections between push strength and the movement of the ball. Encourage students to explain that pushing the ball caused it to start moving (PS2.A, CC.2) and that stronger and weaker pushes (CC.3) resulted in the ball moving at different speeds (PS3.C).

Content Area Connection: English

If time allows and students are able, consider prompting students to add words to their sketches. Students can later use their words and sketches to help them recall information from this investigation to answer future questions (CCSS.ELA-Literacy.W.K.8).

Land 3 minutes

Reflect on the investigation process with students.

▸ Why should we all follow the same investigation plan?

- *If we have a plan, then everyone in the class can do the investigation the same way.*
- *We have to do the investigation the same way so we can talk about what happens.*

Emphasize the importance of following a common set of steps. Explain that doing so allows students to compare and discuss their results. Tell students that in future investigations they will play a larger role in the planning process.

Optional Homework

Students ask an adult at home to help them safely explore the effects of stronger and weaker pushes on objects such as toys and doors.

Lesson 8

Objective: Apply knowledge of stronger and weaker pushes and pulls to the anchor phenomenon.

Agenda

Launch (5 minutes)

Learn (27 minutes)

- Revisit Water Model (12 minutes)
- Update Anchor Chart (8 minutes)
- Update Anchor Model (7 minutes)

Land (3 minutes)

Launch 5 minutes

Remind students of what they learned in the previous lesson about how stronger and weaker pushes affected the ball's speed. Replay the video of a tugboat pushing a cargo ship (http://phdsci.link/1577), and then have students respond to the following question.

▶ **How do you think the tugboat could make the cargo ship move faster?**

- *Maybe the tugboat could use a stronger push.*
- *A stronger push made the ball move faster, so I think that could make the ship move faster too.*

Wonder aloud whether students' findings from the previous lesson also apply to objects moving in water. Have students think about key differences between how a ball rolls and how a cargo ship moves.

▶ **During the investigation, we rolled the ball on the carpet. How is the cargo ship's movement different from the ball's movement?**

- *The ball rolled, but the cargo ship doesn't do that. It kind of slides on the water.*
- *The ball moved on the carpet, but the cargo ship moves on the water.*

Agree that rolling a ball in the classroom is different from moving a cargo ship in water. Explain to students that they will revisit the water model to gather evidence of how stronger and weaker pushes and pulls affect a cargo ship.

Learn 27 minutes

Revisit Water Model 12 minutes

Draw students' attention to the water model. Display the plastic tugboat and wooden block cargo ship, and remind students of the Phenomenon Question **How can a tugboat make a cargo ship move fast or slow?** Tell students to imagine that the sides of the bin are the land around the harbor. Explain that if the cargo ship is moving safely, it should not crash into the sides. Discuss how the class might use stronger and weaker pushes to move the cargo ship safely in the water.

- ▶ Should we use a stronger push or a weaker push to move the cargo ship safely?
  - *We have to use a weaker push to make the cargo ship go slow.*
  - *Maybe we could try both to see what happens in the water model.*

Explain to students that they will observe the effects of both a stronger push and a weaker push on the cargo ship. Then attach the tugboat to the cargo ship with a chenille stem piece to keep the objects aligned with each other, place them in the bin, and gather students around the water model. Tell students they will see the effect of a weaker push on the cargo ship, and use the tugboat to gently nudge the cargo ship forward. Then tell students they will see the effect of a stronger push on the cargo ship, and use the tugboat to push the cargo ship forward with more strength.

Invite students to Think–Pair–Share in response to the following questions. As students discuss their ideas, listen to their responses to evaluate their understanding of the effects of stronger and weaker pushes on the cargo ship.

- ▶ What happened when we used a stronger push?
- ▶ What happened when we used a weaker push?
- ▶ If we wanted to make the cargo ship go fast, would we use a stronger push or a weaker push?
- ▶ If we wanted to make the cargo ship go slow, would we use a stronger push or a weaker push?

Differentiation

After demonstrating the effects of stronger and weaker pushes, consider presenting students with an additional challenge. Prepare to push the cargo ship again, but do not announce the strength of the push. Have students observe the cargo ship's movement after the push to determine whether the push was stronger or weaker.

Teacher Note

Students may notice that a stronger push causes the cargo ship to move farther than a weaker push does. In this lesson, students focus on how the strength of a push or a pull affects an object's speed. During the Engineering Challenge in Lessons 17 through 20, students will explore how the strength of a push or a pull can affect how far an object moves.

Check for Understanding

Students compare the effects of stronger and weaker pushes on the model cargo ship.

Elements Assessed	
SEP.3: Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. PS2.A: Pushes and pulls can have different strengths and directions. CC.3: Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).	
Evidence	**Next Steps**
Students use their observations of the water model demonstration to compare the effects of stronger and weaker pushes on an object's movement (SEP.3). Students identify that stronger (CC.3) pushes cause the model cargo ship to move more quickly, whereas weaker pushes cause it to move more slowly (PS2.A).	If students have difficulty supporting their claims with appropriate evidence, prompt them to share what they noticed during the water model demonstration. If students do not make the connection between push strength and the model cargo ship's speed, consider individually coaching them to test their own pushes with the water model.

Update Anchor Chart 8 minutes

While the class is still gathered around the water model, point out to students that they have explored how stronger and weaker pushes affect objects. Then remind the class that tugboats can also use pulls to move cargo ships, and use the chenille stem piece to attach the plastic tugboat's back end to the wooden block cargo ship. Show the class a pair of stronger and weaker pull cutouts (Lesson 7 Resource).

Teacher Note

Save these cutouts for potential use when updating the anchor model later in Lesson 8 and in future lessons.

Ask students to use what they have learned about stronger and weaker pushes to consider how stronger and weaker pulls might affect the cargo ship.

▶ **What do you think will happen when the tugboat uses a stronger pull?**

- *I think the tugboat will make the cargo ship move fast.*
- *The cargo ship will go all the way to the other side of the bin and crash.*

▶ **What do you think will happen when the tugboat uses a weaker pull?**

- *The block won't move as fast because the boat will only pull it a little bit.*
- *I think the cargo ship won't go as far.*

Tell students they will see the effect of a weaker pull on the cargo ship, and use the tugboat to gently draw the cargo ship forward. Then tell students they will see the effect of a stronger pull on the cargo ship, and use the tugboat to pull the cargo ship forward with more strength. Then lead a discussion to establish that a stronger push or pull can make an object move faster than a weaker push or pull.

▶ **What happened each time we used a weaker push or pull?**

▶ **What happened each time we used a stronger push or pull?**

Summarize student responses on sentence strips, and place the sentence strips on the anchor chart.

Sample anchor chart:

Pushes and Pulls
Starting Movement • Pushes and pulls can cause objects to start moving. • Stronger pushes cause objects to move faster than weaker pushes. • Stronger pulls cause objects to move faster than weaker pulls.

Differentiation

To support student understanding, consider rereading the previous bullet point after posting this new learning.

Adding a drawing beside each bullet point may also be helpful. For example, consider drawing stronger and weaker push symbols next to illustrations of balls moving faster and slower, as shown in the Lesson 7 Activity Guide.

Teacher Note

Students may recall discussing in Lesson 5 that pushes and pulls do not always cause objects to move. If students ask questions about such cases, encourage students to share their ideas about why certain objects do not always move with a push or a pull. Consider guiding students to realize that heavier objects are often more difficult to move than lighter objects. In later levels, as students develop a deeper understanding of how force, mass, and friction relate, they will be able to explain these cases.

Update Anchor Model 7 minutes

Revisit the Phenomenon Question **How can a tugboat make a cargo ship move fast or slow?** Point out to students that they can use what they have learned to answer this question and to update the anchor model. If the anchor model shows the tugboat pulling the cargo ship, use the following questions to guide the anchor model update. If the anchor model shows the tugboat pushing the cargo ship, adapt the following questions accordingly.

- ▶ What kind of pull should the tugboat use to make the cargo ship move slower?
- ▶ How can we show a weaker pull on the anchor model?

Use student responses to justify replacing the current pull cutout on the anchor model with a weaker pull cutout. Then add another sentence below the anchor model to capture what students have learned about how weaker pulls can affect an object's movement.

Teacher Note

The class may have opted to show the tugboat pushing the cargo ship instead of pulling it. If this is the case, update the anchor model with a weaker push rather than a weaker pull.

Sample anchor model:

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

The tugboat uses a weak pull. The cargo ship moves slowly.

Land 3 minutes

Draw students' attention to the anchor chart, and emphasize that students have figured out a lot about how tugboats help move cargo ships. Tell students that in the next lesson they will have a chance to update the driving question board and to show what they know in a Conceptual Checkpoint.

Lesson 9
Starting Movement

Prepare

In Lesson 9, students complete a Conceptual Checkpoint in which they use their Concept 1 learning to explain movement in the context of a skateboard race. Students begin by discussing how using a set of toys to explore movement helped them understand that tugboats use pushes and pulls to help move cargo ships. While preparing for and completing the Conceptual Checkpoint, students view a photograph and illustrations of children using pushes to move other children on skateboards (PS2.A). Students then identify the cause and effect relationship (CC.2) at play in a skateboard race and form a question that helps them determine (SEP.1) which team likely won the race. Finally, students update the driving question board and respond to the Concept 1 Focus Question: **What causes objects to start moving?**

Concept 1: Starting Movement

Focus Question

What causes objects to start moving?

Phenomenon Question

How can a push or a pull help in a skateboard race?

Student Learning

Knowledge Statement

Pushes and pulls can cause objects to start moving. The strength of the pushes and pulls can affect the speed of the objects.

Objective

- Lesson 9: Use knowledge of pushes and pulls to determine the outcome of a skateboard race.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Demonstrating)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.1: Asking Questions and Defining Problems ▪ Ask questions based on observations to find more information about the natural and/or designed world(s).	PS2.A: Forces and Motion ▪ Pushes and pulls can have different strengths and directions. ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS3.C: Relationship Between Energy and Forces ▪ A bigger push or pull makes things speed up or slow down more quickly.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns. CC.3: Scale, Proportion, and Quantity ▪ Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower). *Connections to Nature of Science* Science Is a Way of Knowing ▪ Scientific knowledge informs us about the world.

Materials

		Lesson 9
Student	Conceptual Checkpoint (Lesson 9 Resource C)	●
Teacher	Set of toys from Lesson 4: table tennis ball (1), plastic puck (1), sticky hand (1), toy car (1)	●
	Push and pull chart from Lessons 4 and 5	●
	Skateboard Race Photograph (Lesson 9 Resource A)	●
	Skateboard Race Diagram (Lesson 9 Resource B)	●
Preparation	Prepare to distribute a copy of Lesson 9 Resource C to each student.	●

Lesson 9

Objective: Use knowledge of pushes and pulls to determine the outcome of a skateboard race.

Agenda

Launch (3 minutes)

Learn (27 minutes)

- Prepare for Conceptual Checkpoint (5 minutes)
- Conceptual Checkpoint Part A (5 minutes)
- Conceptual Checkpoint Part B (13 minutes)
- Debrief Conceptual Checkpoint (4 minutes)

Land (5 minutes)

Launch 3 minutes

Display the set of toys that students used to explore movement in Lesson 4, and draw students' attention to the push and pull chart from Lessons 4 and 5. Ask them to Think–Pair–Share in response to the following question:

▶ When we used these toys, what did we learn about how tugboats help move cargo ships?

- *We learned that tugboats use pushes and pulls to move cargo ships, just like we used pushes and pulls to move the toys.*
- *Moving the toys helped us see that objects need a push or pull to start moving.*

Explain that scientists often use what they know about one situation to help them explain a similar situation. Point out that students used what they learned from moving the toys to help them understand how tugboats can help move cargo ships. Tell students that they will now apply their knowledge of pushes and pulls to a new context.

Learn 27 minutes

Prepare for Conceptual Checkpoint 5 minutes

Ask students what they know about racing. Agree that when people race, they move as fast as they can to try to reach a certain place first. Display the photograph of children with a skateboard (Lesson 9 Resource A), and tell the class that people can race on skateboards.

Have students imagine that they each have a partner and that they are getting ready for a skateboard race with another team of two students. Display the skateboard race diagram (Lesson 9 Resource B), and tell students that it shows the race setup. Draw attention to the two teams, the start line, and the finish line. Clarify that each team has a helper (standing) and a rider (sitting); the helper makes the rider move from the start line to the finish line, but the helper must stay at the start line.

Tell students they will use what they know about pushes and pulls and cause and effect to explore the Phenomenon Question **How can a push or a pull help in a skateboard race?**

Conceptual Checkpoint Part A 5 minutes

Distribute a copy of the Conceptual Checkpoint (Lesson 9 Resource C) to each student, and read the first question aloud. Ask students to use the skateboard race diagram to decide whether each helper should use a push or a pull to move each rider.

Teacher Note

If possible, collaborate with the physical education teacher to facilitate a race for students before this lesson.

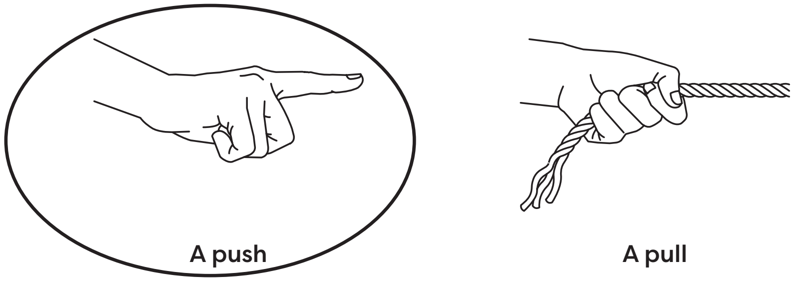
Teacher Note

Consider using a document camera to project the diagram so students can easily refer to it throughout the Conceptual Checkpoint.

Teacher Note

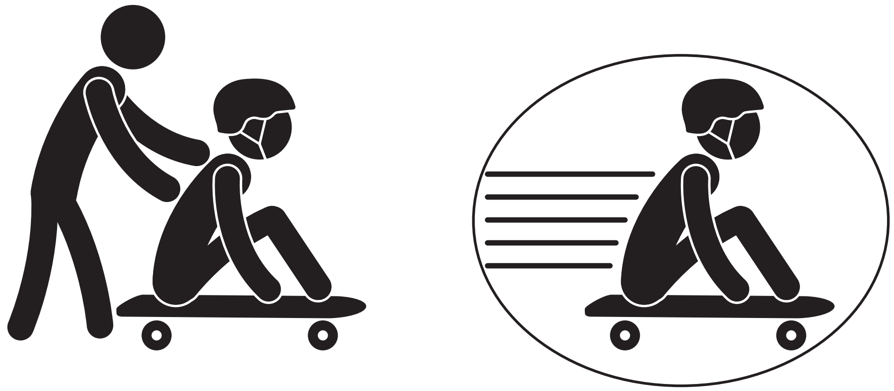
To avoid giving away the first answer in the Conceptual Checkpoint, refrain from using the word *push* when describing the action each team must take. If necessary, say "push or pull."

▶ Will a push or a pull cause each rider to move toward the finish line?



Next, read aloud the second question, and tell students to circle the picture that shows a push's effect.

▶ Which picture shows the effect of a push?



Conceptual Checkpoint Part B 13 minutes

Tell students that the race is over and that the faster team won. Then read the third question aloud, and meet individually with students to write their oral responses at the end of the Conceptual Checkpoint.

Differentiation

If students struggle to dictate a question, remind them of the question words shared in Lesson 3. Suggest that students use words such as *who*, *how*, and *which* to start their questions.

If students are capable of writing, encourage them to write their question in the Conceptual Checkpoint. Supervise to ensure that they capture their question accurately.

▶ What question about strength can you ask to figure out which team was faster?

- *Who pushed harder?*
- *How hard did each helper push?*
- *Which team used a stronger push?*
- *Which team used a weaker push?*

Conceptual Checkpoint

The Conceptual Checkpoint assesses student understanding of the Concept 1 Focus Question: **What causes objects to start moving?**

Elements Assessed	
SEP.1: Ask questions based on observations to find more information about the natural and/or designed world(s). PS2.A: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS3.C: A bigger push or pull makes things speed up or slow down more quickly. CC.2: Events have causes that generate observable patterns. CC.3: Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).	
Evidence	**Next Steps**
Students circle *A push* to indicate the action that will cause each rider to move toward the finish line (PS2.A, CC.2).	If students circle *A pull*, remind them that pushes move objects away and pulls move objects closer. Then ask them whether each helper wants to move the rider away or closer.
Students circle the picture of the rider moving on the skateboard to indicate the effect of the push (PS2.A, CC.2).	If students circle the picture of the push, revisit cause and effect with them. Explain that the effect of a push or a pull is what happens because of the push or the pull.
Students ask a question (SEP.1) about push strength to determine which team was faster (CC.3), demonstrating an understanding that the strength of a push affects rider speed (PS3.C).	If students do not ask a question about push strength, revisit how stronger and weaker pushes affected the speed of the ball in Lesson 7. Explain how knowing the strength of each team's push would help students determine which team was faster.

Teacher Note

Knowing which team used a stronger push is not necessarily enough to accurately determine which team won the race. An accurate determination requires also knowing the masses of the skateboards and the riders, as well as how much friction exists between the skateboards' wheels and the surface of the racecourse. At this level, it is enough for students to apply what they have learned about push strength and object speed to make an educated guess.

Debrief Conceptual Checkpoint 4 minutes

Point out that students have explored how pushes and pulls change the way objects move on water and on surfaces in the classroom. Then highlight that students have now considered how pushes and pulls can help in a skateboard race. Have students think about why the class has used different objects in different settings to explore movement.

▶ Why is it helpful to explore pushes and pulls by using different objects, such as toys, model tugboats, and skateboards?

- *We can see how all the objects are the same. They need a push or a pull to start moving.*
- *Moving the toys around with my hands helps me see how tugboats push ships around just like my hands do.*

Acknowledge that it is helpful for students to find out whether their learning in one situation applies in other situations.

▶ When else do you use pushes and pulls to move an object?

- *I sometimes push my brother in his stroller.*
- *I use pulls when I help my dad get rid of weeds in the garden.*

Explain to students that they can use their science knowledge to better understand what is happening whenever they move objects.

Land 5 minutes

Display the driving question board, and read aloud the question on each sticky note. Have students use a nonverbal signal to show whether they can now answer each question. If students signal that they can answer a question, place the sticky note with that question in a new column below the Essential Question. If students cannot answer a question, leave that sticky note under Unanswered Questions.

Spotlight on Nature of Science

By thinking about movement in different contexts, students see how they can apply knowledge about one phenomenon to related phenomena and thereby gather more information about the world.

Content Area Connection: English

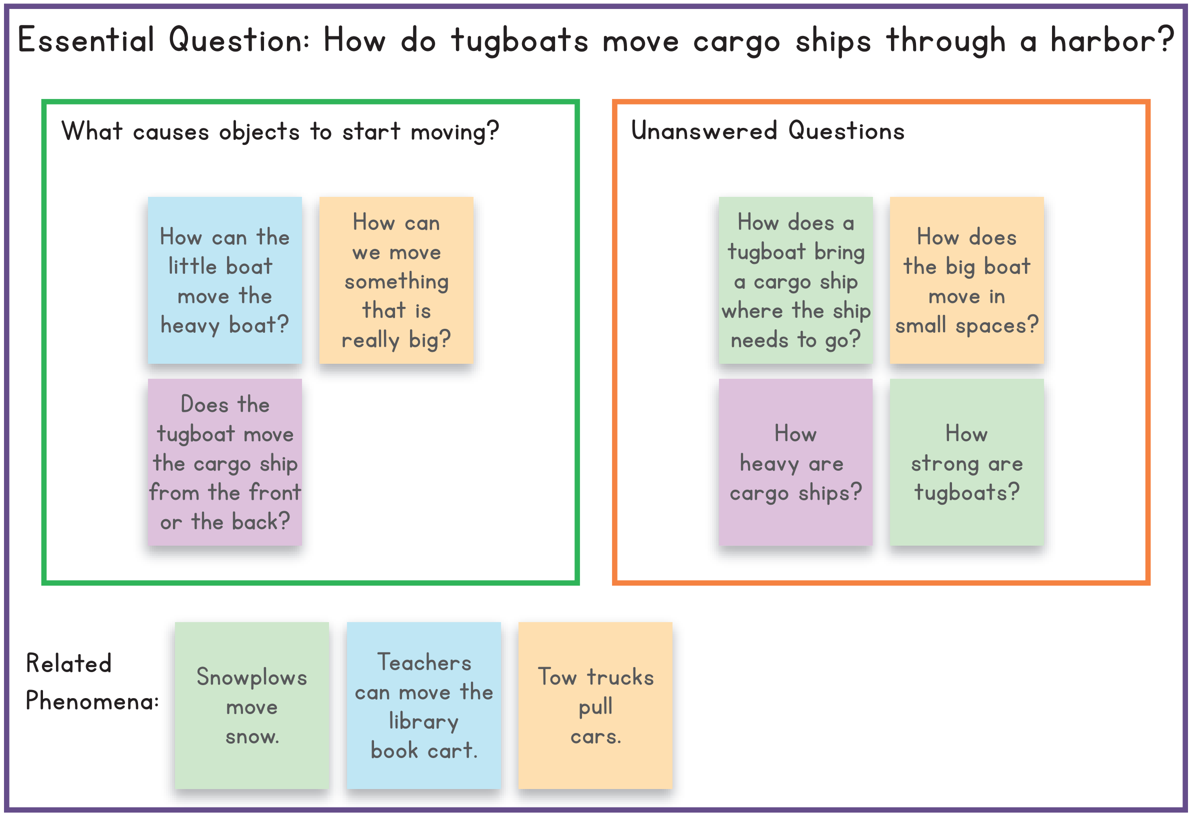
As students present their knowledge and ideas, listen for opportunities to support their speaking skills. Consider offering reminders and feedback on speaking audibly and on expressing thoughts and ideas clearly (CCSS.ELA-Literacy.SL.K.6).

▶ What do you notice about our new group of questions?

- *They are all about how to move something big.*
- *All the questions ask how we can move something.*

Build on student responses to introduce the Concept 1 Focus Question: **What causes objects to start moving?** Record the Focus Question at the top of the new column of questions.

Sample driving question board:



Ask students to reflect on what they have learned so far.

▸ What causes objects to start moving?

- *Objects need a push or a pull to start moving.*
- *Pushes and pulls can make objects move. But sometimes a push or a pull isn't strong enough.*

Optional Homework

While at school and home, students look for other examples of people or objects racing and consider how pushes or pulls help these people or objects move faster.

Lessons 10–12
Changing Direction

Prepare

Students continue their investigation of pushes and pulls in Lessons 10 through 12 by exploring how tugboats can turn cargo ships. In Lesson 10, students plan a collaborative investigation (SEP.3) to explore how tugboats maneuver cargo ships around an obstacle in the water. In Lesson 11, students use the map model to carry out this investigation. They gather evidence of the effects (CC.2) that pushes and pulls have on the direction of a cargo ship's movement. In Lesson 12, students apply their new understanding of how pushing or pulling an object can change the direction of its motion (PS2.A) to the anchor model.

Concept 2: Changing Movement

Focus Question

What causes moving objects to change direction or stop?

Phenomenon Question

How can tugboats turn a cargo ship?

Student Learning

Knowledge Statement

Pushes and pulls can cause moving objects to change direction.

Objectives

- Lesson 10: Plan an investigation to determine how tugboats can turn a cargo ship.
- Lesson 11: Investigate how tugboats use pushes and pulls to turn a cargo ship.
- Lesson 12: Apply new learning about changing the direction of an object's movement to the anchor model.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Developing)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.2: Developing and Using Models ▪ Distinguish between a model and the actual object, process, and/or events the model represents. SEP.3: Planning and Carrying Out Investigations ▪ With guidance, plan and conduct an investigation in collaboration with peers.	PS2.A: Forces and Motion ▪ Pushes and pulls can have different strengths and directions. ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	CC.2: Cause and Effect ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Materials

		Lesson 10	Lesson 11	Lesson 12
Student	Science Logbook (Lesson 10 Activity Guide)	●	●	
	Marker (1)	●		
	Small tugboat cutouts (2 in each lesson)	●	●	
	Glue stick (1)	●	●	
	Direction investigation (1 set per group): prepared chenille stem pieces from Lesson 2 (2), vinyl harbor map (1), prepared wooden block cargo ship from Lesson 2 (1), prepared wooden block tugboats from Lesson 2 (2)		●	
	Science Logbook (Lesson 11 Activity Guide)		●	
	Small push cutouts and small pull cutouts (2 of each)		●	
Teacher	Direction demonstration: prepared chenille stem piece from Lesson 2 (1, only if the anchor model shows the tugboat pulling the cargo ship), vinyl harbor map (1), marker (1), sticky notes (6), prepared wooden block cargo ship from Lesson 2 (1), prepared wooden block tugboats from Lesson 2 (2)	●		
	Two Tugboats Photograph (Lesson 10 Resource A)	●		
	Table tennis ball (1)			●
	Water model materials: prepared plastic bin from Lesson 6 (1), prepared chenille stem pieces from Lesson 6 (2), paper towels, prepared plastic toy tugboats from Lesson 6 (2), prepared wooden block cargo ship from Lesson 6 (1)			●
	Anchor model update: cargo ship cutout from Lesson 2 Resource B (1), stronger and weaker push and pull cutouts from Lesson 7 Resource (1 of each of the 4 cutouts, plus an additional weaker push or pull cutout that matches the cutout added during the Lesson 8 anchor model update), blue tugboat cutout from Lesson 2 Resource B (1), orange tugboat cutout from Lesson 2 Resource B (1), sticky notes (6)			●
Preparation	Prepare small tugboat cutouts, small push cutouts, and small pull cutouts. (See Lesson 10 Resource B.)	●		
	Prepare additional chenille stem pieces and wooden block tugboats as needed for direction investigation. (See Lesson 2 Resource C.) Also, if needed, gather vinyl harbor map, prepared wooden block cargo ship, and prepared wooden block tugboats from direction demonstration for reuse by a group of students in direction investigation.		●	
	Prepare second plastic toy tugboat. (See Lesson 6 Resource.)			●

Lesson 10

Objective: Plan an investigation to determine how tugboats can turn a cargo ship.

Agenda

Launch (8 minutes)

Learn (24 minutes)

- Create Direction Investigation Plan (14 minutes)
- Plan Tugboat Placement (10 minutes)

Land (3 minutes)

Launch 8 minutes

Remind students that they have explored how they can use pushes and pulls to make an object start moving. Tell the class they will explore movement in a new way in this lesson. Have students consider how they would walk from one corner of the classroom to the opposite corner of the classroom without bumping into obstacles.

▶ How would you move from the reading area to the door?

Have a volunteer demonstrate walking from one point to the other. Then invite a second student to take a different path between the same two points.

▶ What was different about the paths they took?

- *They went different ways around the bookcase.*
- *She walked behind the table, and he walked in front of the table.*

Point out that neither student walked in a straight line. Explain to the class that both students had to turn and change direction as they walked to avoid bumping into furniture. Tell students that **direction** is the path someone or something takes when moving.

Teacher Note

This activity requires two areas in the classroom that students cannot walk between by moving in a straight line. If a clear path between opposing corners of the classroom would allow students to cross the room without turning, select a different pair of positions within the classroom.

English Language Development

Introduce the term *direction* explicitly. Providing the Spanish cognate *dirección* may be useful. Explain that people use the word *direction* in different ways. For example, students may follow a direction that tells them what to do. Point out that when talking about movement, people often use *direction* to mean the path along which objects, such as tugboats and cargo ships, move.

Explain that when people want to move in a new direction, they often turn to face that direction. Draw students' attention to the anchor model, and tell them that when cargo ships need to change direction, the ships also turn to face the new direction.

Tell students that the cargo ship on the anchor model needs to move from its current position to the port that has two red cranes (bottom left on the map).

▶ On its way to the port, what should the cargo ship make sure not to hit?

- *The cargo ship has to stay in the water and not hit the land.*
- *It has to move around the island in the middle of the harbor.*
- *It should make sure it doesn't hit those three gray docks.*

As students share, point to each obstacle that the ship must avoid, and explain that a tugboat can help move the cargo ship around these obstacles. Invite students to share their questions about how a tugboat turns a cargo ship to move it in different directions. Add these questions to the driving question board, and build on them to introduce the Phenomenon Question **How can tugboats turn a cargo ship?**

Learn 24 minutes

Create Direction Investigation Plan 14 minutes

Inform students that they will work together to create an investigation plan to help answer the Phenomenon Question **How can tugboats turn a cargo ship?** Write the Phenomenon Question at the top of a sheet of chart paper, and write Our Investigation Plan below the question.

Sample investigation plan:

Our Investigation Plan

Gather students around a map model on the floor for the direction demonstration. Remind them that a model is a tool that people use to help understand or explain something. Place the wooden block cargo ship and one of the wooden block tugboats on the right side of the map, arranging them to match the positions of the cargo ship cutout and tugboat cutout on the anchor model.

Spotlight on Science and Engineering Practices

Throughout this module, students create investigation plans (SEP.3) with increasing independence. In this lesson set, students work with the teacher to plan the steps of the investigation. In their groups, students decide where to place each tugboat and how each tugboat will push or pull on the cargo ship to turn it.

Sample model setup:

Point to the port on the bottom left of the map, and remind students that this is where the cargo ship needs to go.

▶ **How could the tugboat help move the cargo ship to the port?**

Have a few students move their fingers across the map to show different paths the cargo ship could take to reach the port. Acknowledge that the cargo ship could travel to the port by going north of the island or south of the island, but demonstrate that the cargo ship will have more space if it travels north toward the top of the map. Mark this path on the map by using sticky notes with arrows drawn on them.

Sample model setup:

Point out that the cargo ship will need to turn to reach the port.

▶ Do you think a tugboat can turn a cargo ship by pushing or pulling on it?

- *I don't think so. I think pushes and pulls only move objects straight.*
- *I think a tugboat can turn the ship a little.*

▶ How can we use this model to test whether a tugboat's pushes or pulls can turn a cargo ship?

- *We can try using the tugboat to pull the cargo ship around the island.*
- *We might also push with the tugboat when the ship needs to turn.*

Model students' ideas, and demonstrate the challenge of using a single tugboat to move the cargo ship along the curved path. Ask students to think about ways to help the tugboat change direction.

▶ What could we add to the model to help the tugboat turn the cargo ship?

- *I'm not sure how to help. I think the tugboat just has to go slow.*
- *Maybe another tugboat can help it.*

Teacher Note

Although it is possible to use a single tugboat to push or pull the cargo ship around the island, it is challenging to maneuver the cargo ship around tighter turns with just one tugboat. The goal of this demonstration is to introduce the need for a second tugboat.

Consider using one tugboat to alternate between pushing the cargo ship forward from behind and turning the ship with a push from the side so that students see the same tugboat moving back and forth to guide the ship around the island.

Show the class the photograph of two tugboats pushing a cargo ship (Lesson 10 Resource A).

If students suggested adding a second tugboat, confirm that using two tugboats would help. If students did not suggest adding a second tugboat, ask them to count the tugboats they see in the photograph, and have them consider how having two tugboats could help. Then introduce the second wooden block tugboat, and tell students that they will carry out the investigation in the next lesson by using two tugboats on the harbor maps.

▶ How can two tugboats work together to turn the cargo ship?

- *One tugboat can push the cargo ship, and the second tugboat can pull the ship.*
- *Maybe one tugboat can keep the cargo ship moving straight, and the other one can turn it.*

Build on students' responses to establish that one tugboat can move the cargo ship forward while the other tugboat turns the ship so it moves in the correct direction. On the investigation plan, summarize the role of each tugboat, and add a final step to remind students where the cargo ship needs to go.

Sample investigation plan:

Our Investigation Plan
▪ *Use the first tugboat to move the cargo ship forward.* ▪ *Use the second tugboat to turn the cargo ship.* ▪ *Stop the cargo ship at the port.*

Teacher Note

Keep the investigation plan on display throughout the next lesson, during which students conduct the investigation.

Differentiation

To support student understanding, consider adding drawings to the investigation plan.

Plan Tugboat Placement 10 minutes

Place students in investigation groups. Explain to students that they will work together in their Science Logbooks (Lesson 10 Activity Guide) to continue planning how to turn the cargo ship. Guide students to first draw a curved line to show the path the cargo ship will take around the island and to the port. Then ask students to consider where they might place two tugboats so that the tugboats can start to move the cargo ship in the correct direction. Instruct students to share their ideas with their groups.

Distribute two small tugboat cutouts (Lesson 10 Resource B) to each student. Tell groups to decide if they want their first tugboat to push or pull the cargo ship. Then have each student glue one tugboat cutout on the map in their Science Logbooks (Lesson 10 Activity Guide). Next, invite groups to decide where they want to place their second tugboat so they can start to turn the cargo ship. Have each student glue the second tugboat cutout on the map in their Science Logbooks (Lesson 10 Activity Guide).

Sample student response:

Have a few volunteers share their reasoning, and ask the rest of the class to use a nonverbal signal to show whether they think each approach would work.

Check for Understanding

Listen for evidence that students are collaborating with their peers (SEP.3) and using what they have learned to determine where they should push or pull the cargo ship to move it in the correct direction (PS2.A).

As necessary, prompt students to consider how pushes and pulls on different parts of the cargo ship would affect the ship's movement.

Differentiation

If students need more support and would benefit from interacting with the wooden block cargo ships directly, consider providing groups with map models. To avoid spoiling the Lesson 11 investigation, allow students to test how to turn their cargo ship on the reverse side of the vinyl harbor map.

Teacher Note

To help groups depict pulls, consider showing students where they can draw a line on the map in their Science Logbooks to represent the rope between the cargo ship and the tugboat that is pulling it.

Sample student responses:

- *We put the second tugboat next to the cargo ship at the top so it can push the ship down.*
- *We have our second tugboat on the side of the cargo ship, next to the island. We want it to turn the ship up.*

Tell students that they can use their maps in the next lesson to guide their investigation.

Land 3 minutes

Discuss the importance of planning investigations.

▶ **How will our investigation plan help us figure out how tugboats turn cargo ships?**

- *It helps us know how to set up our boats on the map.*
- *Now we know which direction to try to move the cargo ship.*

Point out to the class that group members decided together how they would use the models to carry out the investigation. Tell students they will help even more with decisions the next time the class plans an investigation.

Lesson 11

Objective: Investigate how tugboats use pushes and pulls to turn a cargo ship.

Agenda

Launch (4 minutes)

Learn (25 minutes)

- Investigate Direction (15 minutes)
- Record Observations (10 minutes)

Land (6 minutes)

Launch 4 minutes

Tell students that they will now conduct the investigation they planned in the last lesson. Review each step of the investigation plan with the class, and have students revisit the maps they completed in their Science Logbooks (Lesson 10 Activity Guide). Discuss with students how they should handle the wooden block tugboats and wooden block cargo ship during the investigation.

▶ How can we make the cargo ship move around the island?

- *We can use the tugboats to push and pull the cargo ship.*
- *I don't think we should use our hands to push the cargo ship. We should use the tugboats.*

Clarify for students that they should not use their hands to move the cargo ship and that they should instead push and pull the cargo ship with the tugboats. Remind students that as they investigate with the map model, they should keep the tugboats and cargo ship on the water and off the land.

Learn 25 minutes

Investigate Direction 15 minutes

Place students in their investigation groups, and distribute a set of direction investigation materials to each group. Remind students that they can use the maps in their Science Logbooks (Lesson 10 Activity Guide) to guide how they position their wooden block cargo ship and wooden block tugboats at the start of the turn. Instruct students to use their two tugboats to gently push or pull the cargo ship so that it turns around the island and moves toward the port.

After several minutes, ask students to pause the investigation and share their observations. As students share, have students from other groups use a nonverbal signal to indicate whether they had a similar experience.

▸ What have you noticed about turning the cargo ship?

- *It's hard to turn the cargo ship with just one tugboat. Another tugboat has to push from the side.*
- *We can use pushes and pulls to turn the cargo ship.*

▸ How have you used pushes or pulls in your investigation? ✓

- *We used a pull to keep moving the ship forward.*
- *We made one tugboat push the side of the ship to turn the ship around the island.*

▸ Did the plan you made in your Science Logbook work to turn the cargo ship?

- *Yes. We used the tugboats like we planned, and they turned the ship.*
- *Our plan didn't work, but we found better spots to put the tugboats.*

Allow groups to return to their map models for a few minutes to test new ideas or to explore strategies that students in other groups described. Emphasize that students can use pushes and pulls in several different ways to move the cargo ship from its starting point in the harbor to its destination, the port.

Extension

Students can carry out the investigation with additional obstacles in the harbor, such as boats made of clay.

Differentiation

Kindergarten students may need guidance as they work in groups. As necessary, monitor to ensure that students take turns maneuvering the tugboats and cargo ships. Consider pairing students within groups and having pairs take turns using the two tugboats to move and turn the cargo ship.

Check for Understanding

Listen for evidence that students used their knowledge of pushes and pulls to make their cargo ship change direction. Also listen for student responses that mention the cause of the cargo ship's movement and the effects of the tugboats' pushes and pulls (CC.2). While circulating, encourage students to describe the actions that move the cargo ship. Provide students with a sentence frame such as the following: The tugboat is _____ (pushing/pulling) the cargo ship to make the cargo ship _____.

Record Observations 10 minutes

Bring the class back together, and distribute two small tugboat cutouts (Lesson 10 Resource B) to each student. Explain to students that they will glue the tugboat cutouts into their Science Logbooks (Lesson 11 Activity Guide) to record their investigation results. Draw students' attention to the position of the cargo ship on the map. Tell students to glue their two tugboat cutouts on the map to show where their group placed the tugboats to push or pull the cargo ship at that location.

After students have glued their tugboat cutouts, distribute two small push cutouts and two small pull cutouts (Lesson 10 Resource B) to each student. Have students determine whether each of their tugboats used a push or a pull. Then guide students to glue a push cutout or a pull cutout next to each tugboat cutout on the map.

Sample student response:

Land 6 minutes

Invite students to share additional observations with the class.

▶ **How did you use your two tugboats to turn the cargo ship around the island?**

- *We made the two tugboats work together to make the cargo ship change direction.*
- *Both of our tugboats pushed the cargo ship. One made the ship turn, and the other one moved it forward.*

▶ **How did you use the second tugboat to make the cargo ship turn?**

- *The second tugboat had to push the side of the cargo ship to make the ship turn.*
- *Our second tugboat pulled the front of the cargo ship to the side.*

Emphasize student responses that mention using pushes or pulls on the side of the cargo ship to make the ship turn. Tell students that in the next lesson they will observe how pushes and pulls turn the cargo ship in the water model.

Lesson 12

Objective: Apply new learning about changing the direction of an object's movement to the anchor model.

Agenda

Launch (5 minutes)

Learn (26 minutes)

- Revisit Water Model (10 minutes)
- Update Anchor Model (8 minutes)
- Update Anchor Chart (8 minutes)

Land (4 minutes)

Launch 5 minutes

Have students sit in a circle on the floor. Roll a table tennis ball to one student, and have the student catch it and roll it back.

▶ What caused this ball to move?

- *You pushed the ball.*
- *You took turns pushing it back and forth.*

Select another student, and tell this student to try to change the direction of the ball's movement instead of catching it. Before rolling the ball, ask the class how the student can make the ball change direction without stopping it.

Sample student responses:

- *She can push the ball while it's moving.*
- *I think she should push it from the side.*

Agree that when the ball is close enough, and while it is still moving, the student should give it a gentle push. Roll the ball, and have the student demonstrate how to change its direction.

- ▶ How do you think changing the ball's direction is similar to turning a cargo ship in a harbor? How is it different?
  - *I think they both need a push to change direction.*
  - *The cargo ship might need a stronger push than the ball because the ship is a lot bigger.*

Explain to students that they will investigate whether pushes and pulls can also cause the cargo ship in the water model to change direction.

Learn 26 minutes

Revisit Water Model 10 minutes

Gather the class around the water model, and show students that the model now includes two plastic tugboats instead of only one. Ask students to Think–Pair–Share in response to the following question:

- ▶ How can we make the cargo ship change direction when it is moving?

As students share their ideas, have other students use a nonverbal signal to indicate whether they had a similar idea. Let pairs of students test their ideas, with one student using a tugboat to move the cargo ship forward and the other student using a tugboat to turn the moving cargo ship.

After several pairs test their ideas for turning the cargo ship, ask students to reflect on whether their ideas were successful.

Sample student responses:

- *I thought we should push the cargo ship from the side, and that worked to turn it.*
- *My idea was to pull the back of the ship just a little bit. It did not work very well.*

Content Area Connection: Mathematics

Students may describe size or weight differences between the ball and a cargo ship. Although this lesson does not provide details of these measurable attributes, students can use their observations to infer that the ball is smaller and lighter than a cargo ship (CCSS.Math.Content.K.MD.A.1).

Teacher Note

To make the water model easier for students to interact with, consider hooking the first tugboat to the cargo ship and positioning this tugboat against the cargo ship's side. Then students can use the second tugboat to push or pull the cargo ship forward and the first tugboat to turn the moving cargo ship with a pull from the side.

Differentiation

To help students organize their thinking, consider providing a sentence frame such as the following: My idea was to ______. It (worked/did not work).

▶ How can the tugboats make the cargo ship move in a new direction?

- *One tugboat can push the cargo ship forward. The other tugboat can push the ship on the side to turn the ship.*
- *The second tugboat can also pull the ship to the side to make the ship move in a new direction.*

▶ How does this model help us understand how real tugboats turn cargo ships in a harbor?

- *It shows us that pushes and pulls can turn an object in the water, just like they did on the floor.*
- *It lets us test ways that real tugboats might push and pull a cargo ship to turn it.*

Check for Understanding

Students describe how pushes and pulls cause the model cargo ship to change direction, and they consider whether real tugboats turn cargo ships by using pushes and pulls in the same way.

Elements Assessed	
PS2.A: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. CC.2: Simple tests can be designed to gather evidence to support or refute student ideas about causes. SEP.2: Distinguish between a model and the actual object, process, and/or events the model represents.	
Evidence	**Next Steps**
Students describe a sideways push or pull from the second model tugboat as the cause of the change in direction for the model cargo ship (PS2.A, CC.2).	If students need support to explain how a push or pull caused a change in direction, ask follow-up questions such as these: What happened after the second tugboat pushed the cargo ship? What do you think would happen if the second tugboat did not push the cargo ship?
Students recognize that testing their ideas with the water model can help them consider how real tugboats use pushes and pulls to turn cargo ships (SEP.2, PS2.A).	If students easily recognize that the water model helps them understand how real tugboats could turn cargo ships, challenge them to consider the limitations of the water model.

Update Anchor Model 8 minutes

Draw students' attention back to the anchor model. Point out to students that they have modeled different ways tugboats can turn cargo ships, both on the floor and in the water. Ask students to think about how they can update the anchor model so it shows one way that tugboats can turn a cargo ship around the island.

Then work with students to update the anchor model with another cargo ship cutout (Lesson 2 Resource B), another blue tugboat cutout (Lesson 2 Resource B), an orange tugboat cutout (Lesson 2 Resource B), and two stronger or weaker push or pull cutouts (Lesson 7 Resource). To convey to students that the tugboat moving the cargo ship forward is the same as the original tugboat, use the blue tugboat cutout to depict the tugboat that is moving the cargo ship forward. Next to this new blue tugboat cutout, place the same weaker push or pull cutout that appeared in the previous update (e.g., if the previous update showed the blue tugboat moving the cargo ship forward with a weaker pull, also place a weaker pull cutout beside the blue tugboat in this update). Then use students' input to add the orange tugboat cutout on the side of the cargo ship along with one of the four stronger or weaker push or pull cutouts.

Teacher Note

Consider helping students track the route the cargo ship takes by adding sticky notes with arrows drawn on them to mark the path around the island. For simplicity, the sticky notes are not shown on the sample anchor model. Do not draw directly on the vinyl harbor map, as even dry erase marker may not come off.

Sample anchor model:

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

The tugboat uses a weak pull. The cargo ship moves slowly.

The orange tugboat pushes the side of the cargo ship to help turn the ship.

Update Anchor Chart 8 minutes

Help students reflect on using the models and a table tennis ball to learn about how to turn an object.

▶ How is moving a table tennis ball similar to moving a cargo ship? How is it different?

- *Both the ball and a cargo ship need a push or a pull to start moving or to turn.*
- *The ball is a lot smaller and easier to push than a cargo ship.*

▶ How can we make a moving object change direction?

- *We need to use a push or a pull.*
- *We can push or pull the object from the side. That can make it turn.*

Agree that pushes and pulls can cause objects to change direction, and record this new learning on a sentence strip. Post the sentence strip on the anchor chart.

Sample anchor chart:

Pushes and Pulls
Starting Movement • Pushes and pulls can cause objects to start moving. • Stronger pushes can cause objects to move faster than weaker pushes. • Stronger pulls can cause objects to move faster than weaker pulls.
Changing Movement • Pushes and pulls can turn moving objects.

Content Area Connection: English

Consider pairing students with partners who were not in their investigation groups and having them share their ideas while following classroom rules for discussions. Reflecting on new learning with peers helps students deepen their conceptual understanding and allows them to practice speaking and listening (CCSS.ELA-Literacy.SL.K.1).

Land 4 minutes

Revisit the Phenomenon Question **How can tugboats turn a cargo ship?** Ask students to reflect on how using the map models and the water model helped them answer this question.

Sample student responses:

- *We got to test different ideas to see which ones worked.*
- *The models showed us that some of our ideas didn't work. We learned that pushes from the side worked the best to turn the cargo ship.*

Agree that the models allowed students to test their ideas and helped students determine how pushes and pulls can change the direction of a cargo ship's movement.

Optional Homework

Students tell a family member about how they investigated the ways that pushes and pulls can change the direction of an object's movement. If possible, students use objects at home, such as a ball or a toy car, to demonstrate how pushes or pulls from the side can turn a moving object.

Lessons 13–15
Slowing Down and Stopping

Prepare

In Lessons 13 through 15, students continue to investigate how pushes and pulls can change the way objects move as the class considers the Phenomenon Question **How can a tugboat make a cargo ship slow down and stop?** In Lesson 13, students plan a collaborative investigation (SEP.3) to explore how a tugboat can make a cargo ship slow down and stop. In Lesson 14, students conduct the investigation and revisit the water model. Then students update the anchor model to reflect their new understanding of how tugboats can use pushes and pulls to make cargo ships slow down and stop (PS2.A). Students broaden their understanding in Lesson 15 by observing that when two objects bump into each other, each object pushes on the other, which can cause changes in movement (CC.2).

Concept 2: Changing Movement

Focus Question

What causes moving objects to change direction or stop?

Phenomenon Question

How can a tugboat make a cargo ship slow down and stop?

Student Learning

Knowledge Statement

Pushes and pulls can cause moving objects to slow down and stop.

Objectives

- Lesson 13: Plan an investigation to explore how a tugboat can make a cargo ship slow down and stop.
- Lesson 14: Investigate how a tugboat uses pushes and pulls to make a cargo ship slow down and stop.
- Lesson 15: Identify simultaneous pushes between a pair of objects.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Developing)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.3: Planning and Carrying Out Investigations ▪ With guidance, plan and conduct an investigation in collaboration with peers. ▪ Make predictions based on prior experiences.	PS2.A: Forces and Motion ▪ Pushes and pulls can have different strengths and directions. ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns. CC.3: Scale, Proportion, and Quantity ▪ Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).

Materials

		Lesson 13	Lesson 14	Lesson 15
Student	Science Logbook (Lesson 13 Activity Guide)	●	●	
	Small tugboat cutout, small push cutout, and small pull cutout from Lesson 10 Resource B (1 of each)	●		
	Glue stick (1)	●		
	New York Harbor Knowledge Deck card (1)		●	
	Slowing down and stopping investigation (1 set per student pair): prepared chenille stem piece from Lesson 2 (1), vinyl harbor map (1 per group), prepared wooden block cargo ship from Lesson 2 (1), prepared wooden block tugboat from Lesson 2 (1)		●	
	Prepared wooden block cargo ship from Lesson 2 (1 per student pair)			●
	Prepared wooden block tugboat from Lesson 2 (1 per student pair)			●
Teacher	Model comparison demonstration: vinyl harbor map (1), water model materials, prepared wooden block cargo ship from Lesson 2 (1)	●		
	Water model materials: prepared plastic bin from Lesson 6 (1), paper towels, prepared wooden block cargo ship from Lesson 6 (1)	●	●	●
	Additional water model materials: prepared chenille stem from Lesson 6 (1), prepared plastic toy tugboat from Lesson 6 (1)		●	
	Anchor model update: cargo ship cutout from Lesson 2 Resource B (1), stronger and weaker push and pull cutouts from Lesson 7 Resource (1 of each of the 4 cutouts), stop sign cutout (1), blue tugboat cutout from Lesson 2 Resource B (1)		●	
	Hall's car (1)			●

		Lesson 13	Lesson 14	Lesson 15
Preparation	Cue "Milano Bridge Accident" (Li 2020) video and mute sound: http://phdsci.link/1587.	●		
	Prepare for model comparison demonstration by setting up a vinyl harbor map next to the water model and placing a wooden block cargo ship from a map model onto the map.	●		
	Prepare enough small tugboat cutouts, small push cutouts, and small pull cutouts for every student to have one of each. (See Lesson 10 Resource B.)	●		
	Prepare additional wooden block cargo ships as needed for the slowing down and stopping investigation. (See Lesson 2 Resource C.) Also, if needed, gather vinyl harbor map and map model wooden block cargo ship from model comparison demonstration for reuse by a group of students in the slowing down and stopping investigation.		●	
	Prepare stop sign cutout. (See Lesson 14 Resource.)		●	

Lesson 13

Objective: Plan an investigation to explore how a tugboat can make a cargo ship slow down and stop.

Agenda

Launch (6 minutes)

Learn (25 minutes)

- Explore Difference between Models (10 minutes)
- Plan Stopping Investigation (15 minutes)

Land (4 minutes)

Launch 6 minutes

Revisit the anchor model, and remind students that the tugboats are trying to move the cargo ship around the island and to the port.

▶ **How are the tugboats using pushes and pulls to help move the cargo ship toward the port?**

- *One tugboat is using a weaker pull to make the cargo ship move slowly.*
- *The other tugboat is pushing the side of the cargo ship to make the ship turn around the island.*

Ask students how the cargo ship's movement needs to change as the ship gets closer to the port.

Sample student responses:

- *It needs to slow down so it doesn't crash.*
- *It will need to stop by the port.*

Tell students that they will watch a video of a cargo ship crashing into a crane at a port (Li 2020) (http://phdsci.link/1587). Play the video with the sound muted.

Invite students to Think–Pair–Share in response to what they notice and wonder about the video.

Differentiation

To support English learners, consider modeling a few sample responses by using the following sentence frame:

I noticed ______, and it made me wonder ______.

Sample student responses:

- *I noticed the cargo ship hit the big blue crane, and it made me wonder how the ship could break something so big.*
- *I noticed that the cargo ship crashed into the port, and it made me wonder why the ship didn't stop.*
- *I noticed the tugboat pulling on the cargo ship, and it made me wonder why the ship moved away from the tugboat.*

As students share what they wonder, record their questions on individual sticky notes, and add the sticky notes to the driving question board. Highlight the fact that the tugboat is pulling on the cargo ship to try to move it toward the tugboat, and remind students that sometimes pushes and pulls are not strong enough to move an object. Then wonder aloud whether a stronger pull from the tugboat would have been enough to stop the cargo ship from crashing, and introduce the Phenomenon Question **How can a tugboat make a cargo ship slow down and stop?** Tell students that they will plan an investigation to try to answer this question.

Teacher Note

In the video, the rope connecting the tugboat to the cargo ship is most visible from 0:54 to 1:03. If needed, replay this portion of the video so students can notice the rope.

Learn 25 minutes

Explore Difference between Models 10 minutes

Prepare for the model comparison demonstration by gathering students around the water model and a map model. Display the wooden block cargo ship from the water model and a wooden block cargo ship from a map model. Then ask students whether they have noticed a difference between how each ship moves. If necessary, guide students to think about how the two cargo ships slow down and stop.

Sample student responses:

- *In the water model, the cargo ship moves on water. But in the map model, the cargo ship moves on the map.*
- *I think it's easier to move the cargo ship on the water.*

Highlight student responses about the water model cargo ship moving farther, more easily, more quickly, or for a longer time than the map model cargo ship. Then demonstrate the difference in how the two ships move by simultaneously using one hand to push the water model cargo ship and the other hand to push the map model cargo ship. Tell students to pay attention to which cargo ship stops first and to compare how far the cargo ships move.

▶ How is one cargo ship's movement different from the other cargo ship's movement?

- *The cargo ship on the water goes far.*
- *The cargo ship on the map stops moving right after the push.*

Point out that in each model the cargo ship moves on top of something. Explain that when the cargo ship slides on the map, the ship and the map rub against each other, which slows down the cargo ship and makes it stop sooner. Tell students that when the cargo ship moves on water, the ship and the water do not rub against each other as much, so the cargo ship moves farther in the water model.

Explain to students that they will use the map models to investigate how tugboats can make a cargo ship slow down and stop. Tell students they will need to start by figuring out how to make the cargo ship keep moving on the map.

▶ How can we make the cargo ship on the map move like the cargo ship on the water?

- *We need to keep the cargo ship moving for longer.*
- *Maybe we can keep pushing the cargo ship to keep it moving.*

Highlight responses that suggest using a continuous push so that the cargo ship keeps moving. Tell students that as they make their investigation plans, they should keep in mind that the cargo ship needs to be moving so that they can try to slow it down and stop it.

Plan Stopping Investigation 15 minutes

Tell students they will work in pairs to plan their investigation. Ask the class to think about how they planned investigations in previous lessons.

▶ What are some important ideas to remember when we plan an investigation?

- *We all have to follow the same investigation plan.*
- *We need to decide what materials we'll use and how we'll use them.*

Teacher Note

The difference in how the cargo ship moves on water and how it moves on the map is most clear when both ships receive a weak push. Consider testing pushes of different strengths before class to prepare to demonstrate that the cargo ship moves farther in the water model.

Check for Understanding

Listen for students' use of comparative language when they describe the difference in how the cargo ships move on water and on the map (CC.3). For example, students may describe one cargo ship as moving faster or slower, or they may notice that one ship moves farther or for a longer period of time than the other ship.

Teacher Note

Students will learn the term *friction* in Level 3. Kindergarten students should begin to recognize that objects do not slow down and stop on their own.

To provide additional support, discuss or demonstrate how a given object moves across different surfaces. Consider the following examples:

- Kicking a ball across grass versus kicking the same ball across pavement
- Rolling a table tennis ball across carpet versus rolling it across tile

Remind students of the map model materials they can use to conduct the investigation: a chenille stem piece, a vinyl harbor map, a wooden block cargo ship, and a wooden block tugboat. Then place students in investigation pairs.

Have students share ideas with their partner about how to investigate the Phenomenon Question **How can a tugboat make a cargo ship slow down and stop?** Visit each pair, and ask the questions below to help students think about the steps they should include in their investigation plans.

- ▶ How can we make the cargo ship move without using the tugboat?
- ▶ How can we use the tugboat to stop the cargo ship?
- ▶ How can you and your partner help each other carry out the investigation?

After a few minutes, bring the class back together to create an investigation plan. Record the Phenomenon Question at the top of a sheet of chart paper, and write Our Investigation Plan below the question.

Sample investigation plan:

Our Investigation Plan

Revisit the questions above, and use student responses to develop the investigation plan.

- ▶ How can we make the cargo ship move without using the tugboat?
  - *We can use our hands to push the cargo ship.*
  - *One person can push the cargo ship so it goes forward.*
- ▶ How can we try using the tugboat to stop the cargo ship?
  - *We can see if the tugboat can push the cargo ship back.*
  - *We can test pulls at different spots on the cargo ship.*

Differentiation

While conducting the investigation in the next lesson, each pair will share one vinyl harbor map with at least one other pair. If students would benefit from more support while planning, consider having two pairs collaborate as a group of four instead of working as separate pairs.

Spotlight on Science and Engineering Practices

In this lesson set, students continue to develop their investigation planning skills (SEP.3). To provide additional guidance, ask questions such as the following:

- What question are we trying to answer?
- How can we use the map model to help us answer the question?
- What steps should we include in our plan?

Teacher Note

Post the class plan so that students can refer to it as they conduct the investigation in the next lesson. Consider adding drawings to the plan to support student understanding.

▶ How can you and your partner help each other carry out the investigation?

- *I'll push the cargo ship forward, and my partner can use the tugboat to stop the ship.*
- *We'll talk to each other about what happens.*

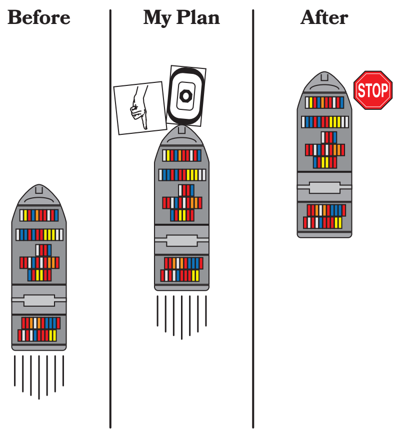
Sample investigation plan:

Our Investigation Plan
▪ *One partner uses a hand to push the cargo ship forward.* ▪ *One partner uses the tugboat to push or pull the cargo ship backward.* ▪ *Share what you see.*

Place students in their investigation pairs again. Tell students that they will record in their Science Logbooks (Lesson 13 Activity Guide) how they plan to work with their partner to make the cargo ship stop. Have students look at the image in the first column, and explain that it shows the cargo ship moving. Then point out the image in the third column, and tell students that it shows the cargo ship after it has stopped. Finally, direct students to look at the second column, and explain that this is where they will show how they plan to make the cargo ship slow down and stop.

Distribute one small tugboat cutout, one small push cutout, and one small pull cutout (Lesson 10 Resource B) to each student. Instruct students to glue a tugboat cutout in the second column to show where they will place the tugboat. Then tell students to glue either a push cutout or a pull cutout next to the tugboat cutout to show how they plan to use the tugboat to stop the cargo ship.

Sample student response:



Land

4 minutes

After students have finished recording their plans in their Science Logbooks (Lesson 13 Activity Guide), have them share how they decided where to place their tugboat cutout and push or pull cutout.

▸ What is your plan for stopping the cargo ship? Why do you think that will work?

- *Our plan to stop the cargo ship is to use the tugboat to pull the cargo ship back. I think our plan will work because sometimes at recess I pull my swing back to make it stop.*
- *Our plan is to push the front of the cargo ship. I think that will stop the ship because yesterday I stopped a ball with a push.*

As students share, have the rest of the class use a nonverbal signal to show whether they agree, and highlight responses in which students use their observations to make predictions.

Content Area Connection: English

Develop students' language skills by encouraging students to use complete sentences to describe their plans for stopping a cargo ship (CCSS.ELA-Literacy.L.K.1.F). To help students articulate their ideas, consider providing the following sentence starter: Our plan to stop the cargo ship is ….

Teacher Note

To encourage students to share about prior experiences that may have informed their plan, consider asking the following questions: Can you think of a time when you tried to stop a moving object? What worked then? What did not work?

Remind students that when people notice a pattern in their observations, they can use that pattern to make predictions, or figure out what is likely to happen. Record a few predictions that students agree about at the bottom of the investigation plan, and tell students that they will follow the investigation plan in the next lesson.

Lesson 14

Objective: Investigate how a tugboat uses pushes and pulls to make a cargo ship slow down and stop.

Agenda

Launch (4 minutes)

Learn (24 minutes)

- Investigate Slowing Down and Stopping (16 minutes)
- Make Predictions with Water Model (8 minutes)

Land (7 minutes)

Launch 4 minutes

Distribute a New York Harbor Knowledge Deck card to each student, and ask students to consider the following question as they examine the photograph on the front of the card.

▶ How do you think tugboats stopped these cargo ships at the port?

- *Tugboats could have pushed on the cargo ships to slow them down.*
- *Maybe a tugboat pushed the cargo ship toward the port and then used a pull to slow it down and stop it.*

Highlight student responses that mention pushes and pulls, and remind students that in this lesson they will investigate whether pushes and pulls can stop a moving object.

Learn 24 minutes

Investigate Slowing Down and Stopping 16 minutes

Instruct students to look at their Science Logbooks (Lesson 13 Activity Guide) to review how they plan to work with a partner to make the wooden block tugboat stop the wooden block cargo ship.

Place students in their investigation pairs, and join two or more pairs into groups that will share a vinyl harbor map. Distribute a tugboat, a cargo ship, and a chenille stem piece to each pair. Then distribute a harbor map to each group, and tell students that each pair will share a harbor map with the other students in their group.

Safety Note

This activity poses potential hazards. Review these safety guidelines with students to minimize the risks:

- Keep fingers away from the front of the tugboat and cargo ship when moving the tugboat and cargo ship.
- Move the cargo ship by holding the sides of the ship from above.
- Do not bump the tugboat or cargo ship into another student's fingers or hand.
- Do not push the tugboat and cargo ship too hard.

Review the investigation plan, demonstrate how to move the tugboat and cargo ship safely, and then instruct students to begin the investigation. After several minutes, prompt students to swap roles so each partner has a chance to handle both the tugboat and the cargo ship.

Gather the materials, and bring the class back together to share observations.

▶ How did you try to slow down and stop the cargo ship?

- *We put the tugboat behind the cargo ship so we could use it to pull the ship backward.*
- *We made the tugboat push on the front of the cargo ship.*

Teacher Note

Consider having students use the reverse side of the harbor map to carry out the investigation so that they are not concerned about keeping the cargo ship and the tugboat on the blue parts of the map.

During the investigation, support students as they model the movement of the cargo ship. The student handling the cargo ship should aim to move the ship slowly and steadily so that the other student is able to use the tugboat to slow the ship.

Content Area Connection: Mathematics

The position of the tugboat in relation to the cargo ship is integral to stopping the ship. This investigation and the discussions students have about it support students' developing ability to describe the relative positions of objects by using terms such as *beside*, *in front of*, *behind*, and *next to* (CCSS.Math.Content.K.G.A.1).

As students share their responses, ask them to reflect on the plans they recorded in their Science Logbooks (Lesson 13 Activity Guide).

▶ Did your plan work?

- *Yes, it did. Our plan to pull back on the cargo ship made the ship stop.*
- *No. But we figured out how to make the cargo ship stop by pushing on it.*

Explain that scientists often change their plans many times and that knowing that a plan does not work can help scientists create a better plan. Tell students to circle *Yes* or *No* in their Science Logbooks (Lesson 13 Activity Guide) to indicate whether their plan worked.

Make Predictions with Water Model 8 minutes

Gather students around the water model, and ask the following question.

▶ **Do you think the tugboat can stop the moving cargo ship by pushing on the front of the ship? Why or why not?**

- *Yes. In our investigation, we stopped the cargo ship by pushing on the front of the ship with the tugboat.*
- *I'm not sure because the other cargo ship was moving on the map, not on water.*

Show students that the tugboat can use a push to slow down and stop the wooden block cargo ship in the water model. First, push the cargo ship with one hand so that the ship starts moving. Then use the plastic tugboat to stop the cargo ship by pushing on the ship from the front.

▶ **Do you think the tugboat can stop the moving cargo ship by pulling on the back of the ship? Why or why not?**

- *Maybe. The tugboat in the video didn't stop the cargo ship by pulling on the ship, but a pull worked in our investigation. I think a pull might stop the ship if the pull is strong or if the ship isn't going very fast.*
- *Yes. Pulling on the back of the ship with the tugboat stopped the cargo ship on the map, so I think pulling on the back will stop the cargo ship in the water model too.*

Extension

If students' plans did not successfully slow and stop the cargo ship, consider having students glue a new tugboat cutout and a new push or pull cutout on the page to reflect what did work in the investigation. Students can color their new cutouts to distinguish them from their original set.

Students can also add drawings, symbols, or words to the column in their Science Logbooks (Lesson 13 Activity Guide). Some students may want to show the direction of their tugboat's push or pull.

Check for Understanding

Students will spend the next several minutes making predictions. Listen for students to support their predictions with prior events or experiences (SEP.3).

If students do not mention personal experiences, prompt them with questions such as these: What have you noticed before that can help you make a prediction? Have you ever used a push or a pull to stop something from moving?

Teacher Note

To demonstrate the tugboat's push, connect the tugboat to the front of the cargo ship before using one hand to push the ship. When the ship is moving, use the tugboat to push the ship backward.

Show students that the tugboat can use a pull to slow down and stop the cargo ship in the water model. First, push the cargo ship with one hand so that the ship starts moving. Then use the tugboat to stop the cargo ship by pulling on the ship from the back.

▶ Were your predictions right?

- *Yes. I thought using the tugboat to push on the front of the cargo ship would stop the ship, and it did.*
- *I was right. I thought that the tugboat could pull on the back of the cargo ship to make the ship stop.*

Acknowledge that the tugboat can slow down and stop the moving cargo ship on the water by using a push or a pull.

Land 7 minutes

Draw students' attention to the anchor model, and point to the port in the bottom-left corner. Tape a cargo ship cutout (Lesson 2 Resource B) parallel to the port. Then guide students through a brief discussion about how they can show a tugboat stopping the cargo ship at the port by adding another blue tugboat cutout (Lesson 2 Resource B) and one of the stronger or weaker push or pull cutouts (Lesson 7 Resource).

If the class chooses to show the tugboat in front of the cargo ship pushing the ship back, ask students whether they want to show the tugboat using a stronger push or a weaker push. Then place the selected push cutout next to the tugboat. If the class chooses to show the tugboat behind the cargo ship pulling the ship back, ask students whether they want to show the tugboat using a stronger pull or a weaker pull. Then attach the selected pull cutout next to the tugboat.

Finally, tape the stop sign cutout (Lesson 14 Resource) next to the cargo ship, and add a sentence below the model to explain this stopping interaction.

Teacher Note

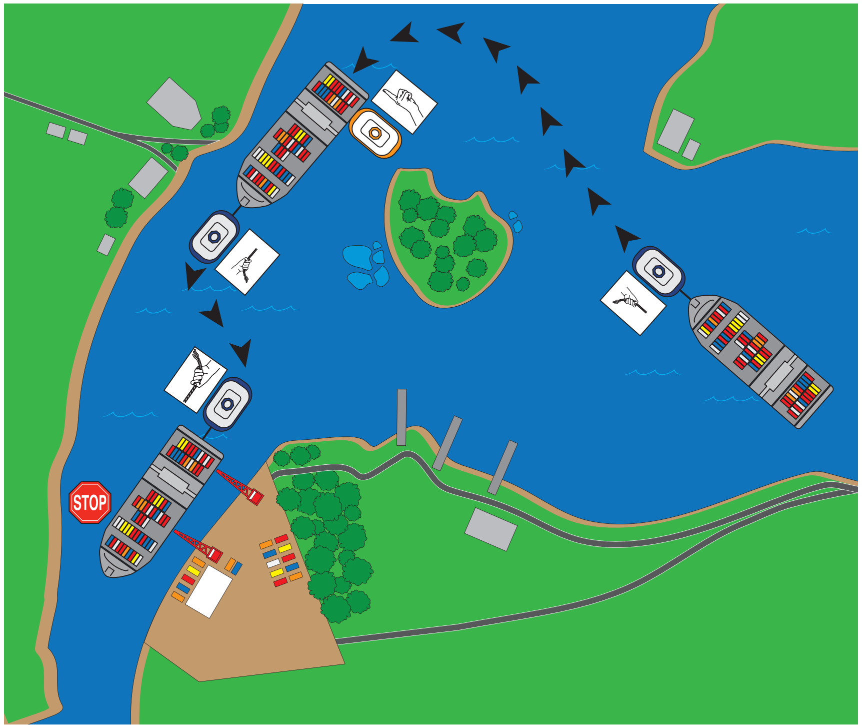
To demonstrate the tugboat's pull, connect the tugboat to the back of the cargo ship before using one hand to push the ship. When the ship is moving, use the tugboat to pull the ship backward.

Teacher Note

The class may correctly place any of the four cutouts on the anchor model. However, if a ship is moving quickly, a weak push or a weak pull may not be sufficient. Consider playing the cargo ship crash video (http://phdsci.link/1587) again to highlight that even though the tugboat is pulling back on the cargo ship, the ship is moving too quickly for the tugboat to stop it. Then suggest that a stronger pull could have stopped the ship.

Sample anchor model:

Tugboats Moving a Cargo Ship



A tugboat pulls a cargo ship toward the port.

The tugboat uses a weak pull. The cargo ship moves slowly.

The orange tugboat pushes the side of the cargo ship to help turn the ship.

The blue tugboat uses a pull to stop the cargo ship.

Lesson 15

Objective: Identify simultaneous pushes between a pair of objects.

Agenda

Launch (10 minutes)

Learn (20 minutes)

- Explore Collisions with Water Model (10 minutes)
- Update Anchor Chart (10 minutes)

Land (5 minutes)

Launch 10 minutes

Remind students that in the previous lesson they were able to stop the wooden block cargo ship by pushing on the front of the ship with the wooden block tugboat. Then tell students they will use their hands to act out this push between the tugboat and the cargo ship. Hold up an open hand with the palm facing the class, and explain that this hand represents the tugboat. Then invite one student to use an open hand to represent the cargo ship. Face the student, and move the open-palmed "tugboat" hand slowly toward the student's open-palmed "cargo ship" hand. Ask the student to move the cargo ship hand slowly as well, until both hands are pushing against each other. Push against the student's hand with mild to moderate force, making sure not to cause the student discomfort.

▶ What do you feel?

- *I feel your hand pushing against mine.*

Acknowledge that the tugboat hand is pressing against the cargo ship hand, and comment that it feels as though the student's hand is also pushing. Then swap roles so that the student's hand is the tugboat hand, and repeat the demonstration.

▶ Wow, I feel your tugboat hand pushing hard against mine! Do you feel any pushes on your hand too?

- *I think so. It kind of feels like your hand is pushing against mine, even though my hand is the tugboat.*

Teacher Note

If the student does not report feeling a push, pause the demonstration, and have the student hold an open-palmed hand in midair. Guide the student to recognize that the student does not feel any push against their palm in this moment. Then repeat the demonstration, and ask the student to compare the two sensations.

Divide the class into pairs, and have students try this activity with their partner. Tell students that one student in each pair will use a hand to represent the cargo ship and that the other student will use a hand to represent the tugboat. Explain that the student acting out the cargo ship should move a hand forward slowly and gently, just as students moved the wooden block cargo ship forward during the investigation in the previous lesson. Then explain that the student acting out the tugboat should push back gently against the cargo ship hand to stop that hand from moving forward. Ask students to pay attention to the pushes they feel on their hand. Then have students swap roles so that each student has a chance to act out the tugboat and the cargo ship.

Safety Note

This activity poses potential hazards. Review these safety guidelines with students to minimize the risks:

- Do not push too hard against another student's hand.
- Push only into each other's open hands. Do not touch any other part of another student.
- Remain seated throughout the activity.

Circulate during the activity, and ask pairs the following question.

▶ Which hand is pushing on the other, or are both hands pushing?

- *I feel the tugboat hand pushing on the cargo ship hand.*
- *My hand is pushing, and I think I feel the cargo ship hand pushing too.*

Highlight student responses that mention not just the tugboat hand pushing on the cargo ship hand but also the cargo ship hand pushing back. Tell students that they will continue to explore what happens when two objects, such as the tugboat and cargo ship, bump into each other.

Learn 20 minutes

Explore Collisions with Water Model 10 minutes

Gather students around the water model, and tell them to watch the following demonstration carefully. Place the wooden block cargo ship in the bin, and push the cargo ship hard so that it hits one side of the bin and bounces backward. Ask students to Think–Pair–Share about what they noticed, and highlight responses that mention the cargo ship bouncing back after hitting the side of the bin. Then ask the following question.

▶ What do you think caused the cargo ship to change direction?

- *I think the cargo ship bounced off the side of the bin.*
- *The cargo ship went backward because it hit the side.*

Agree that the cargo ship changed direction because it hit the side of the bin. Tell students that the side of the bin caused the cargo ship to move away.

▶ Do you think the side of the bin made the cargo ship move away with a push or a pull?

- *Pulls move objects closer, so I don't think the bin pulled on the ship.*
- *I think the side of the bin pushed the cargo ship away.*

Explain to students that when the cargo ship and the bin touched each other, both objects pushed on each other, just as students' hands pushed on each other in the Launch activity.

Tell students that they will continue to explore what happens when two objects, such as the wooden block cargo ship and plastic bin, bump into each other.

Update Anchor Chart 10 minutes

Have students sit in a circle on the floor, and show them the Hall's car. Push the car toward a student, and tell that student to stop the car. Then ask the class how the student used a push or a pull to make the car stop.

Differentiation

If students struggle to grasp this concept, they may benefit from interacting individually with the water model. Consider having students take turns pushing the cargo ship hard and observing that it bounces off the side of the bin.

Differentiation

Demonstrating this interaction with a heavier object will help students feel the push from the object when it bumps into them. Keeping safety in mind, consider using a heavier object, such as a basketball, to help students feel the push from the object as they use a push to stop the object.

Sample student responses:

- *He pushed the car to make it stop.*
- *His hand pushed the front of the car, so it stopped.*

Instruct the student to push the car toward a second student, and have that student stop the car and push it along to a third student. Allow this sequence to continue for a few rounds so students can observe a pattern of events that their classmates' actions caused.

Check for Understanding

Students use their knowledge of pushes and pulls to explain how to slow down and stop an object.

Elements Assessed	
PS2.A: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. CC.2: Events have causes that generate observable patterns.	
Evidence	**Next Steps**
Students explain that pushing on the Hall's car can make it slow down and stop (PS2.A).	If students struggle to explain what caused the Hall's car to stop, have them push the car forward. Then perform a clear pushing action to slow down and stop the car. Ask students whether a push or a pull stopped the car.
Students notice the following pattern: When their classmates push on the front of the moving Hall's car, the car slows down and stops. Students identify these pushes as causes of the car's change in movement (CC.2).	If students have difficulty explaining what causes the Hall's car to slow down and stop, point out similarities in how students are stopping the car. Ask students to act out how they would stop the car, and help them identify their pushing or catching action as the cause of the car stopping.

As time permits, allow as many students as possible to stop the Hall's car with their hand, and tell them to pay attention to how it feels when the car bumps into them.

▶ What do you feel when you stop the car with your hand?

- *I feel the car bump into my hand.*
- *The car pushes on my hand a little bit.*

Summarize student responses by explaining that when the car bumps into a student's hand, the hand pushes on the car to stop it and the car also pushes on the hand. Record students' new learning on sentence strips, and add the sentence strips to the anchor chart.

Sample anchor chart:

Pushes and Pulls
Starting Movement • Pushes and pulls can cause objects to start moving. • Stronger pushes cause objects to move faster than weaker pushes. • Stronger pulls cause objects to move faster than weaker pulls.
Changing Movement • Pushes and pulls can turn moving objects. • Pushes and pulls can slow down and stop moving objects. • When objects touch, they both push on each other.

Land 5 minutes

Revisit the Phenomenon Question **How can a tugboat make a cargo ship slow down and stop?** Invite students to share their responses to this question.

Spotlight on Disciplinary Core Ideas

In Concept 2 and during the Engineering Challenge, students explore the idea that when objects touch, they push on each other (PS2.B).

To support student understanding, consider sharing other examples of pushes students can feel when they bump into an object or when an object bumps into them. Examples may include bumping into a desk and catching a ball.

Invite students to share a time when they pushed on an object and felt a push from that object.

Sample student responses:

- *Tugboats can pull back on cargo ships to slow them down and stop them.*
- *A tugboat can also push on the front of a cargo ship to stop it.*

▶ When the tugboat pushes on the cargo ship, what happens to the tugboat?

- *The tugboat gets pushed by the cargo ship.*
- *The cargo ship also pushes on the tugboat.*

Point out to students that they have learned a lot about how pushes and pulls can start, change, and stop movement. Tell students that in the next lesson they will get to show what they know in a Conceptual Checkpoint.

Optional Homework

With adult supervision, students roll two objects (such as balls, markers, or marbles) into each other on a hard, slippery surface such as wood or tile. Students explain to their family members that both objects push on each other and that these pushes can change the movement of one or both objects.

Lesson 16
Changing Movement

Prepare

In Lesson 16, students complete a Conceptual Checkpoint in which they use their Concept 2 learning to explain the role of pushes and pulls in soccer. Students begin by watching two soccer videos and observing how the players push and pull the ball to change the direction of its movement (PS2.A). During the Conceptual Checkpoint, students determine whether soccer players use pushes or pulls to cause the ball to move away from themselves (CC.2) and in different directions. Then, students observe and compare images (SEP.3) to identify which one shows what happens when a ball bumps into a wall. Finally, students work as a class to update the driving question board and respond to the Concept 2 Focus Question: **What causes moving objects to change direction or stop?**

Concept 2: Changing Movement

Focus Question

What causes moving objects to change direction or stop?

Phenomenon Question

How do people use pushes and pulls when they play soccer?

Student Learning

Knowledge Statement

Pushes and pulls can cause moving objects to change direction or stop.

Objective

- Lesson 16: Identify how soccer players use pushes and pulls to change the movement of the ball.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Demonstrating)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. *Connections to Nature of Science* Scientific Investigations Use a Variety of Methods ▪ Scientists use different ways to study the world.	PS2.A: Forces and Motion ▪ Pushes and pulls can have different strengths and directions. ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns.

Materials

		Lesson 16
Student	Conceptual Checkpoint (Lesson 16 Resource)	●
	Small push cutouts and small pull cutouts from Lesson 10 Resource B (2 of each)	●
	Glue stick (1)	●
Preparation	Cue children playing soccer video and two soccer players video: http://phdsci.link/1588 and http://phdsci.link/1589.	●
	Prepare to distribute a copy of Lesson 16 Resource to each student.	●
	Prepare enough small push cutouts and small pull cutouts for every student to have two of each. (See Lesson 10 Resource B.)	●

Lesson 16

Objective: Identify how soccer players use pushes and pulls to change the movement of the ball.

Launch 5 minutes

Tell students that in this lesson they will think about pushes and pulls in a game of soccer. Invite students to share what they know about soccer and to describe their experiences playing the game.

Show students the video of children playing soccer (http://phdsci.link/1588).

▸ How are the children using pushes or pulls in the game?

- *When they kick the ball, I think they're using pushes.*
- *They can kick the ball different ways to make it go in different directions.*

Ask students whether they think soccer players ever pull the ball closer to themselves. Tell students they will now watch another soccer video. Instruct them to use a nonverbal signal when they notice a pull. Then play the video of two soccer players (http://phdsci.link/1589).

Play the second video one more time, and ask the class to pay attention to how the player wearing white shorts uses pushes and pulls to make the ball start moving, to change the direction of the ball's movement, and to slow the ball down.

Tell students they will use what they have learned about pushes, pulls, and movement to explore the Phenomenon Question **How do people use pushes and pulls when they play soccer?**

Agenda

Launch (5 minutes)

Learn (25 minutes)

- Conceptual Checkpoint Part A (10 minutes)
- Conceptual Checkpoint Part B (10 minutes)
- Debrief Conceptual Checkpoint (5 minutes)

Land (5 minutes)

Teacher Note

If possible, partner with the physical education teacher to arrange for students to play soccer before this lesson.

Learn 25 minutes

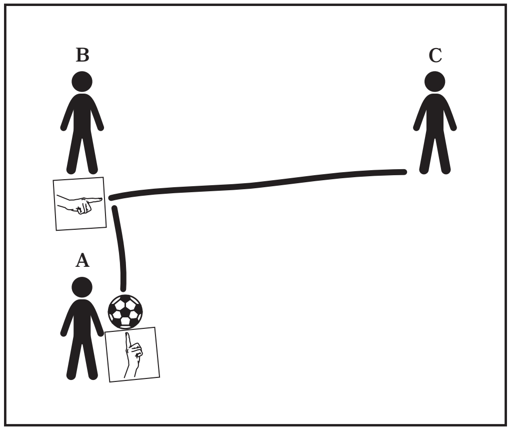
Conceptual Checkpoint Part A 10 minutes

Distribute a copy of the Conceptual Checkpoint (Lesson 16 Resource) to each student, and help students find the first question. Read aloud the following scenario, and then instruct students to draw lines to show the ball's path.

▶ Player A kicks the ball to Player B. Player B kicks the ball to Player C. What is the path of the ball?

Allow students time to draw their lines. Then distribute two small push cutouts and two small pull cutouts (Lesson 10 Resource B) to each student. Explain to students that they should glue one cutout on the picture to show how Player A uses a push or a pull to move the ball to Player B. Then instruct students to glue a second cutout on the picture to show how Player B uses a push or a pull to move the ball to Player C.

Sample student response:



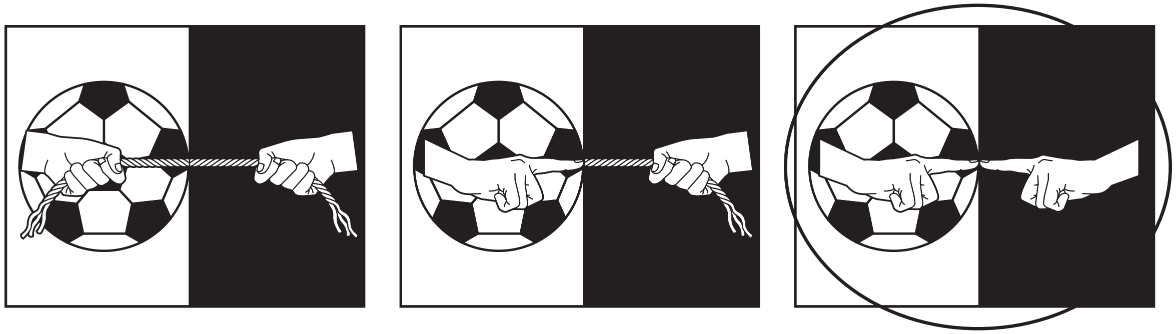
Differentiation

If students have trouble identifying the ball's path, reread the scenario slowly, and have students use a finger to trace where they think the ball moves.

Conceptual Checkpoint Part B 10 minutes

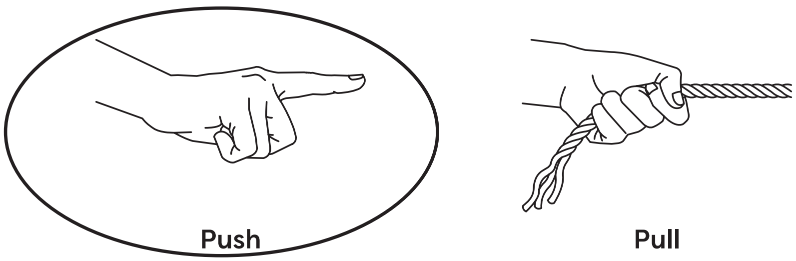
Help students find the second question, and provide time for them to look at the pictures. Point out the black rectangle on the right side of each picture, and explain to students that this is a wall. Then read aloud the following scenario, and instruct students to circle one of the three pictures.

▶ **While the players are playing soccer, one player kicks the ball at a wall. What happens when the ball hits the wall?**

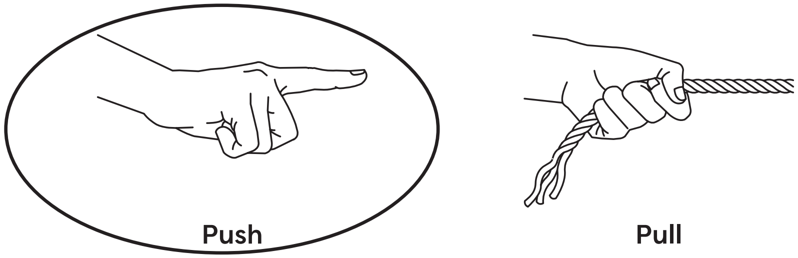


Then have students circle their answers to the final two questions to confirm what happens.

▶ **Does the ball push or pull on the wall?**



▶ Does the wall push or pull on the ball?



Conceptual Checkpoint

The Conceptual Checkpoint assesses student understanding of the Concept 2 Focus Question: **What causes moving objects to change direction or stop?**

Elements Assessed	
SEP.3: Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. PS2.A: Pushes and pulls can have different strengths and directions. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS2.B: When objects touch or collide, they push on one another and can change motion. CC.2: Events have causes that generate observable patterns.	
Evidence	**Next Steps**
Students draw lines showing how the ball moves away from Player A to Player B and away from Player B to Player C. Then students glue two push cutouts onto the picture: one next to Player A that points toward Player B and another next to Player B that points toward Player C (PS2.A, CC.2).	If necessary, act out the scenario with a table tennis ball and craft sticks. Use the craft sticks to represent the players, and have students watch where the ball moves.
Students compare the three pictures and select the third one (SEP.3). Then they circle *Push* twice to answer the final two questions, demonstrating that they understand that both objects push on each other (SEP.3, PS2.B).	If students do not recognize that the ball and wall push on each other when they touch, repeat the Lesson 15 hands demonstration or water model demonstration, or bounce a table tennis ball off a wall of the classroom and ask students why they think the ball moved away from the wall after it hit the wall.

Debrief Conceptual Checkpoint 5 minutes

After students finish the Conceptual Checkpoint, guide them to reflect on the use of pushes and pulls in soccer.

▶ How do soccer players use pushes and pulls?

- *The players can use pushes to make the ball start moving.*
- *They can use pushes to make the ball change direction.*
- *We saw in the video that players can also use their feet to pull the ball back.*

Highlight student responses that mention soccer players using pushes and pulls to move the ball, to change its direction, or to stop it.

▶ How have we explored the ways that pushes and pulls can change movement?

- *We used the map model to see how a tugboat can use pushes and pulls to turn a cargo ship.*
- *We pushed the table tennis ball to change where it went.*

Help students recall all the different ways they have investigated pushes and pulls: by using the water model, the map model, the toys, the Hall's car, and their hands and by watching videos of dancers, tugboats, and soccer players.

▶ Why is it helpful to explore pushes and pulls in many ways?

- *It helps us see that what we did to stop the cargo ship on the map also stopped the ship on the water.*
- *It shows us that pushes and pulls work the same way, even when we use them on something new.*

Content Area Connection: Mathematics

When students reflect on their learning from the module investigations, they recognize patterns in the ways that pushes and pulls affect movement. In doing so, students develop skills that appear in the Standards for Mathematical Practice (CCSS.Math.Practice.MP7).

Explain that when scientists study something, they try to explore it in many ways. Tell students that by exploring pushes and pulls in many ways they are learning a lot about how objects move in the world.

Land 5 minutes

Display the driving question board, and read aloud the unanswered questions on each sticky note in the second column. Have students use a nonverbal signal to show whether they can now answer each question. As students respond, keep the newly answerable questions in the second column, and place the questions that still cannot be answered in an open space next to the driving question board.

▶ **What do you notice about our new group of questions?**

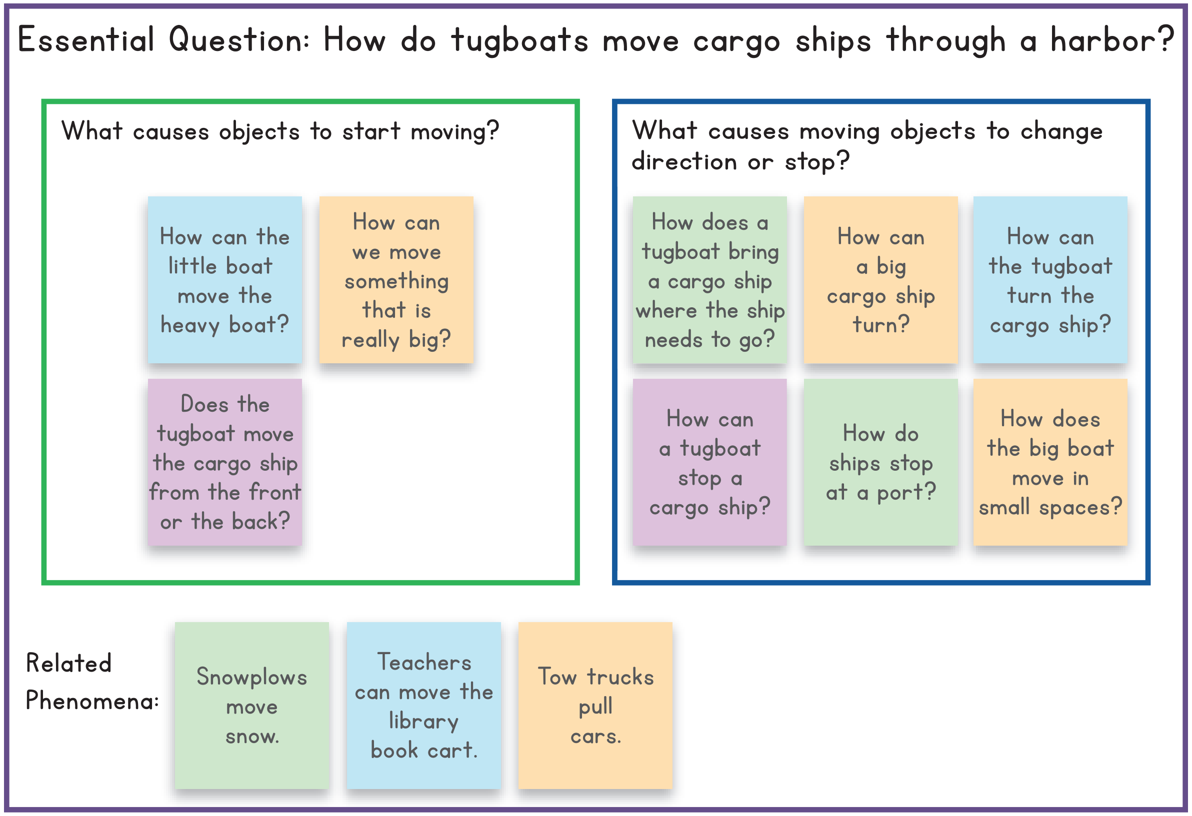
- *A lot of the questions are about how to turn something.*
- *Some questions are about how to get ships to slow down and stop.*

Use student responses to develop the Concept 2 Focus Question: **What causes moving objects to change direction or stop?** Record the Focus Question at the top of the second column.

Teacher Note

The end-of-module lessons will address the unanswered questions in the space next to the driving question board.

Sample driving question board:



Ask students to reflect on their Concept 2 learning.

- ▶ How can we change the way an object is moving?
  - *We can push or pull the side of an object to make it turn when it's moving.*
  - *Pushes and pulls can also make a moving object slow down and stop.*

Summarize for students that they explored two ways to change an object's movement: They can use a push or a pull to make a moving object turn, and they can use a push or a pull to make a moving object stop.

Optional Homework

Students look for pushes and pulls while they watch or play sports. Then they think about whether each push or pull caused an object's movement to change.

Lessons 17–20
Engineering Challenge

Prepare

In previous lessons, students developed an understanding that when objects touch, they push on each other and can change each other's movement (PS2.B). In Lessons 17 through 20, students use that knowledge to solve a problem during an Engineering Challenge. They follow the engineering design process to develop a model of a cushion that would prevent a tugboat from bouncing too far away from its dock. In Lesson 17, students define the problem. In Lesson 18, students test materials and create sketches of their dock cushions. In Lesson 19, students build their cushion devices (SEP.6), conduct tests to gather evidence about the effects of their designs (CC.2), and then work to improve their cushions. Finally, in Lesson 20, students share their cushions with the class and analyze the data they collected to determine which designs are most effective.

Application of Concepts

Task

Engineering Challenge

Phenomenon Question

How can we help a tugboat stop close to a dock?

Student Learning

Knowledge Statement

People can use the engineering design process to create a device that helps a tugboat stop close to a dock.

Objective

- Lessons 17–20: Apply the engineering design process to create a model cushion that helps a tugboat stop close to a dock.

Standards Addressed

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Demonstrating)

K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull. (Demonstrating)

K–2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem. (Demonstrating)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons. ▪ Make observations (firsthand or from media) and/or measurements of a proposed object, tool, or solution to determine if it solves a problem or meets a goal. SEP.5: Using Mathematics and Computational Thinking ▪ Use counting and numbers to identify and describe patterns in the natural and designed world(s). ▪ Decide when to use qualitative vs. quantitative data. SEP.6: Constructing Explanations and Designing Solutions ▪ Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem.	ETS1.A: Defining Engineering Problems ▪ A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. ETS1.B: Developing Possible Solutions ▪ Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. PS2.A: Forces and Motion ▪ Pushes and pulls can have different strengths and directions. ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.1: Patterns ▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. CC.2: Cause and Effect ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.

Materials

		Lesson 17	Lesson 18	Lesson 19	Lesson 20
Student	Science Logbook (Lesson 17 Activity Guide)	●			
	Imagine stage (1 set per group): prepared Dock Cushion Testing Station (1 per 2 groups), prepared Imagine stage testing bag (1), green marker (1), red marker (1), yellow marker (1), sticky notes (3)		●		
	Science Logbook (Lesson 18 Activity Guide)		●	●	●
	Plan stage: crayons, small tugboat cutout from Lesson 10 Resource B (1), glue stick (1)		●		
	Create stage (1 set per group): prepared Create stage materials, prepared Dock Cushion Testing Station (1 per 2 groups), blunt tip scissors (at least 1), tape			●	
	Final dock cushion (1 per group)				●
Teacher	Engineering Challenge Rubric (Lesson 17 Resource A)	●			
	Tugboat (Garland 2014)	●			
	Tugboat in New York Harbor Photograph (Lesson 17 Resource B)	●			
	Engineering Design Process Visual (Lesson 17 Resource C), sticky note or magnet (1)	●	●	●	●
	Wooden block tugboat demonstration: prepared Dock Cushion Testing Station (1), vinyl harbor map (1), prepared wooden block tugboat from Lesson 2 (1)	●			
	Tugboat at a Dock Photograph (Lesson 17 Resource D)	●			
	Dock Cushion Testing Station setup materials (1 set per station): 5 cm × 15 cm × 2 cm wooden blocks (2), 6 qt clear plastic bin with lid (1), books or other objects that can serve as weights (5 lb), smooth clipboard (1), prepared tugboat cutout from Lesson 17 Resource G (1, optional), Hall's car (1), color copy of Lesson 17 Resource E (1 for use in Lessons 17 and 18 only), color copy of Lesson 19 Resource (1 for use in Lesson 19 only), masking tape, plastic rulers (3) **Note:** Lesson 17 requires one station. Lessons 18 and 19 require four stations.	●	●	●	
	Dock Cushion Testing Station demonstrations: prepared Dock Cushion Testing Station (1), prepared Imagine stage testing bag (1 for use in Lesson 18 only)	●	●	●	

		Lesson 17	Lesson 18	Lesson 19	Lesson 20
Teacher	Imagine stage testing bags preparation: resealable plastic snack bags (8), cotton balls (30), jumbo craft sticks (4), medium wedge erasers (6), nonhardening modeling clay ($\frac{1}{4}$ lb), braided cotton rope (2.5 ft), scissors (1), sponges (2), tape		●		
	Markers in green, red, and yellow (1 of each color)		●		
	Sticky notes (13 in Lesson 18; 12 in Lesson 20)		●		●
	Results chart: results chart header illustrations (1 set), marker (1), tape		●	●	●
	Create stage materials preparation: resealable plastic snack bags (8), cotton balls (120), jumbo craft sticks (32), medium wedge erasers (48), nonhardening modeling clay (2 lb), braided cotton rope (20 ft), scissors (1), sponges (8)			●	
	Dock Cushion Photographs (Lesson 20 Resource)				●
Preparation	Prepare dock cushion testing stations, and prepare to demonstrate the testing station classroom procedure for students. (See Lesson 17 Resource F.)	●	●	●	
	Consider affixing a tugboat cutout to each Hall's car. (See Lesson 17 Resource G.)	●			
	Prepare for wooden block tugboat demonstration. Place a vinyl harbor map facedown on a flat surface, adjacent to a weighted-down plastic bin from one of the testing stations. (Make sure to use the side of the bin that is not facing the ramp.) Practice pushing a wooden block tugboat across the map with enough force for the tugboat to bump into the bin and bounce back at least a couple of inches.	●			
	Prepare Imagine stage testing bags. (See Lesson 17 Resource F.)		●		
	Prepare results chart header illustrations. (See Lesson 18 Resource.)		●		
	Prepare enough small tugboat cutouts for every student to have one. (See Lesson 10 Resource B.)		●		
	Prepare Create stage materials. (See Lesson 17 Resource F.)			●	

Lesson 17

Objective: Apply the engineering design process to create a model cushion that helps a tugboat stop close to a dock.

Agenda

Launch (5 minutes)

Learn (27 minutes)

- Think about Tugboat Docking (5 minutes)
- Set Up Problem and Solution Chart (15 minutes)
- Demonstrate Testing Procedure (7 minutes)

Land (3 minutes)

Launch 5 minutes

Teacher Note

Review the Engineering Challenge rubric (Lesson 17 Resource A) before beginning Lessons 17 through 20. Use the rubric to assess students throughout the Engineering Challenge by looking and listening for evidence of engagement as students participate in each stage of the engineering design process. The Checks for Understanding in each lesson identify points at which to gather evidence.

Revisit pages 8–9 of the book *Tugboat* (Garland 2014) with students. Display the illustration, and draw students' attention to the position of the tugboat.

▶ Why do you think the tugboat needs to be close to the dock?

- *I think the tugboat needs to be close so it's safe for the crew and captain to get on and off it.*
- *If the tugboat was too far away, people couldn't get onto it.*

Display the photograph of a tugboat in New York Harbor (Lesson 17 Resource B). Ask students to imagine that the tugboat in the photograph is returning to its dock after a day of moving cargo ships through the harbor and that the tugboat captain needs to get back to the dock fast. Tell students that because the captain cannot slow down, the tugboat will bump into the dock.

Content Area Connection: English

When revisiting pages 8–9 of the book *Tugboat*, consider reading the text aloud while displaying the illustration. Students may not be familiar with the words *captain*, *crew*, and *board*. By hearing these words in context and by using them in their responses, students build their vocabulary and improve their comprehension of the Engineering Challenge scenario (CCSS.ELA-Literacy.L.K.4).

Teacher Note

To encourage student engagement, consider telling the class to imagine that the tugboat captain is hurrying back to the dock for a specific reason. For example, the captain could be rushing to get to a birthday party or to bring a sick crew member back to shore.

Remind students that they have been learning about what happens when objects bump into each other. Explain that bumping into a dock does not usually damage a tugboat or harm its passengers but that it can cause another problem. Ask students where they think the tugboat might stop if it bumps into the dock after moving fast.

Sample student responses:

- *I'm not sure where the tugboat will stop. But it needs to stop close to the dock so the captain can get off it.*
- *I think it will stop away from the dock because the dock might push the tugboat away.*

Explain that in the next few lessons students will use their knowledge of pushes and pulls to try to solve a problem. Then introduce the Phenomenon Question **How can we help a tugboat stop close to a dock?**

Display the engineering design process visual (Lesson 17 Resource C). Have students turn to the same visual in their Science Logbooks (Lesson 17 Activity Guide). Point out and explain the six stages of the process: Ask, Imagine, Plan, Create, Improve, and Share. Tell students that during the next few lessons they will follow these steps, just as engineers do, to help solve a problem.

Differentiation

When the class begins each stage of the engineering design process, consider introducing a hand signal for that stage.

Ideas for signals include the following.

- Ask: Raise a hand.
- Imagine: Point to the head.
- Plan: Act out writing or drawing.
- Create: Act out building something.
- Improve: Give a thumbs-up with one hand and then add a thumbs-up with the other hand.
- Share: Move hands outward from the chest until arms are outstretched.

Learn 27 minutes

Think about Tugboat Docking 5 minutes

Direct students' attention to the Ask stage on the engineering design process visual (Lesson 17 Resource C) by placing a sticky note or magnet next to the stage. Remind students that engineers start the design process by asking questions so they can understand the problem they need to solve.

Explain to students that they will observe what happens when a tugboat does not slow down before it reaches its dock. Gather students around the vinyl harbor map, weighted-down bin, and wooden block tugboat. Have students imagine that the bin is the tugboat's dock, and tell students that the tugboat will move across the map and bump into the dock.

▶ What do you predict will happen when the tugboat bumps into the dock? Why do you think that?

- *I think the tugboat will hit the dock and make a loud noise.*
- *I predict that the tugboat will stop when it hits the dock because the dock will push on it.*

Push the wooden block tugboat across the vinyl map and toward the dock from about 6 inches away.

▶ What happened when the tugboat bumped into the dock?

- *The tugboat bounced back away from the dock.*
- *I heard the tugboat make a noise and saw it move away from the dock.*

▶ What caused the tugboat to move away from the dock?

- *The dock pushed the tugboat away.*
- *When the tugboat and the dock bumped, they pushed on each other.*

Highlight student responses that mention pushes between the tugboat and the dock, and confirm that the push from the dock caused the tugboat to move away from the dock.

Teacher Note

If the class does not have the vinyl harbor map, test that the wooden block tugboat slides well enough across a desk or table surface to bounce back a couple of inches after hitting the bin. If the surface is too rough, slide the tugboat across a sheet of printer paper, chart paper, or butcher paper.

Once again, display the photograph of the tugboat in New York Harbor (Lesson 17 Resource B). Remind students that the tugboat needs to stop close to the dock so that people can get on and off the boat safely but that the captain is also in a hurry and cannot slow down. Tell students that the class needs to figure out a way to change how the dock pushes on the tugboat without changing how fast the tugboat is moving when it bumps into the dock.

Display the photograph of a tugboat at a dock (Lesson 17 Resource D).

Have students Think–Pair–Share about what they notice.

Sample student responses:

- *The tugboat is right next to the dock.*
- *The dock and the tugboat both have tires on their sides.*

Confirm that the tugboat has stopped very close to the dock so that people can get on and off it. Guide students to notice the tires and to think about how the tires might help soften the bump between a tugboat and its dock.

Set Up Problem and Solution Chart 15 minutes

Tell students that, like engineers, they will figure out ways to solve a problem. Repeat the Phenomenon Question **How can we help a tugboat stop close to a dock?** Then remind students that in the Ask stage, engineers ask what the problem is and how they might solve it. Create a class problem and solution chart with three columns. Ask students the following question, and use their responses to fill out the first column.

▸ What is the problem?

- *The tugboat bumps into the dock and bounces away.*
- *The tugboat bounces too far away from the dock for people to get on or off the tugboat.*

Record the problem in the first column.

Sample class chart:

What is the problem?		
The dock pushes the tugboat too far away.		

▸ How could we stop the tugboat from bouncing so far away from the dock?

- *We can't slow down the tugboat because the captain is in a hurry, so I'm not sure what to do.*
- *Maybe we could put something like the tires on the dock or the tugboat to make the tugboat bounce less.*

Build on student responses to suggest that adding a cushion to the dock would soften the bump between the tugboat and the dock. If needed, revisit the photograph of a tugboat at a dock (Lesson 17 Resource D) to develop the idea that students can create a cushion that helps the tugboat stop closer to the dock.

Differentiation

Consider adding drawings to the chart to support student understanding.

Remind students of what they already know about stronger and weaker pushes: A stronger push can make an object move faster than a weaker push.

▶ Which kind of push do you think makes an object move farther: a stronger push or a weaker push?

- *I think a stronger push will make something move farther.*
- *Stronger pushes make things move faster, and I think objects go farther when they move faster.*

Guide students to understand that if they can make the push from the dock feel weaker, then they can help the tugboat stop closer to the dock.

Teacher Note

In this Engineering Challenge, students design dock cushions to help a tugboat stop close to a dock. Real tugboats rely on such cushions as shock absorbers. When a tugboat bumps into a dock without a cushion, the two objects contact each other for a very short time. In contrast, when a tugboat bumps into a dock cushion, the contact time is longer. With a dock cushion, because the pushes between the tugboat and the dock deliver their total strength over more time, the strength at any given moment is weaker on average.

In Kindergarten, students only need to recognize that a cushion makes the bump between two objects feel weaker. Students do not need to understand that cushions work by prolonging the contact time.

▶ How can we make the push from the dock feel weaker?

- *We can put a cushion on the dock. Then the dock won't push the tugboat as hard.*
- *If we add pads to the dock, then the push from the dock might feel weaker.*

Use student responses to add a possible solution to the class chart.

Sample class chart:

What is the problem?	What could be a solution?	
The dock pushes the tugboat too far away.	*We can make a cushion that makes the push feel weaker.*	

Teacher Note

Students may have noticed during previous investigations that stronger pushes move objects farther than weaker pushes. If needed, demonstrate stronger and weaker pushes with the wooden block tugboat to show that stronger pushes cause objects to move farther.

Differentiation

If students would benefit from additional support, discuss other examples of cushions to help students understand how cushions can make pushes feel weaker. Ask students whether they have ever worn helmets or safety pads when bicycling, skating, or riding a skateboard. Help students understand that when they bump into an object, these cushions protect them by making the push from the object feel weaker.

Demonstrate Testing Procedure 7 minutes

Explain that, in addition to figuring out a problem and possible ways to solve it, engineers also need to test each solution to see whether it works. Tell students that after they create their cushions, they will need to test how well the cushions work.

Show students the Dock Cushion Testing Station without the measurement paper (Lesson 17 Resource E) in place. Explain to students that they will use this setup to test their cushions. Show students the Hall's car, and tell them that they will use the car to represent a tugboat and the bin to represent a dock.

Remind the class that it is important for all students to follow the same procedure for testing so that they can compare and discuss results. Then discuss how the class could use the ramp to make the car move the same way in each test.

Release the Hall's car down the ramp so that it hits the bin and bounces back. Point out that the Hall's car bounced back just as the wooden block tugboat did.

▶ Why do both tugboats bounce away from the dock?

- *The tugboats both bounce away because they hit the dock.*
- *The dock pushes on both tugboats when the tugboats bump into it.*

Confirm that in both cases the dock pushes the tugboat away when the tugboat bumps into the dock. Then ask students how they can use the Dock Cushion Testing Station to test their cushions.

Sample student responses:

- *We can bump the tugboat into our cushions to see if they work.*
- *We can see if the tugboat stops close to the dock after it bumps into our cushions.*

Agree that students can place their cushions against the dock so that the tugboat bumps into them. Then remind students that they need a way to check how well their cushions work. Show students the measurement paper (Lesson 17 Resource E). Have them consider how they could use the color zones on the paper to note how far back the tugboat bounces after each bump.

Spotlight on Crosscutting Concepts

Throughout the Engineering Challenge, students will repeatedly assess how effective their cushions are at stopping the tugboat close to the dock (CC.2).

Teacher Note

Consider affixing a tugboat cutout (Lesson 17 Resource G) to the Hall's car to help students imagine that it is a tugboat.

Check for Understanding

Listen for evidence that students recognize the similarities in how the two model tugboats move after bumping into the dock (SEP.3) and that students identify a pattern: The dock pushing on the tugboats causes the tugboats' movement to change (CC.1, PS2.B).

If students do not recognize this pattern, repeat the demonstrations, and ask students to notice similarities between the two.

To monitor student progress, use the Engineering Challenge rubric (Lesson 17 Resource A).

Differentiation

Students with color vision deficiencies, commonly known as color blindness, may need support during this activity. Point out that the green zone is at the top of the sheet, the yellow zone is in the middle, and the red zone is at the bottom.

For resources to help students with color vision deficiencies, see this page on the National Science Teaching Association website: http://phdsci.link/1512.

Slide the measurement paper into its position under the rulers. Then invite two volunteers to help demonstrate how to use the measurement paper to describe how far the tugboat bounces after hitting the dock. Follow the procedure outlined in Lesson 17 Resource F.

Point to the part of the dock that the tugboat bumps into, and have students imagine that they have placed their cushion there. Prompt students to consider how they will know whether their cushion works.

Sample student responses:

- *If the cushion works, the tugboat should stop closer to the dock.*
- *The tugboat should stop in the green zone if our cushion works well.*

Confirm that students will know that a cushion works if it helps the tugboat stop closer to the dock than the tugboat did without the cushion. Use student responses to fill out the third column of the class chart.

Sample class chart:

What is the problem?	What could be a solution?	How will we know whether the solution works?
The dock pushes the tugboat too far away.	*We can make a cushion that makes the push feel weaker.*	*The tugboat will stop closer to the dock.*

Land 3 minutes

Draw students' attention back to the Ask stage on the engineering design process visual (Lesson 17 Resource C). Remind students that during this stage engineers ask what the problem is and how they might solve it. Have students Think–Pair–Share about what they did during this stage.

Teacher Note

Bouncing the tugboat into the dock without a cushion will serve as the control (the standard of comparison). Students' goal is to create a cushion that makes the tugboat bounce back as little as possible.

Teacher Note

Keep this chart on display for the class to refer to throughout the Engineering Challenge.

Teacher Note

Consider attaching the photograph of a tugboat at a dock (Lesson 17 Resource D), or a copy of page 9 of the book *Tugboat*, to the engineering design process visual to remind students of their goal throughout the Engineering Challenge.

Sample student responses:

- *We figured out what the problem is. The dock pushes the tugboat hard, so the tugboat stops too far away.*
- *We also decided to try to solve the problem by making a cushion.*
- *We talked about how we can test our cushions too.*

Tell students that in the next lesson they will move to the Imagine stage.

Optional Homework

Students look for cushions outside of the classroom (e.g., helmets, shin guards, car bumpers, door stops).

Lesson 18

Objective: Apply the engineering design process to create a model cushion that helps a tugboat stop close to a dock.

Agenda

Launch (5 minutes)

Learn (27 minutes)

- Imagine Dock Cushions (20 minutes)
- Plan Dock Cushions (7 minutes)

Land (3 minutes)

Launch 5 minutes

Briefly review the class problem and solution chart with the class, and work with students to summarize what they know so far about the Engineering Challenge.

- ▶ What problem are we trying to solve?
- ▶ What solution will we test?
- ▶ How will we know whether our cushions work?

Display the engineering design process visual (Lesson 17 Resource C), and tell students that in this lesson they will focus on the Imagine and Plan stages of the engineering design process as they brainstorm ways to make their cushions. Move the sticky note or magnet to mark the Imagine stage.

Learn 27 minutes

Imagine Dock Cushions 20 minutes

Remind students that in the Imagine stage engineers explore materials and brainstorm ideas for their solution. Share with students that they will test different materials to see which ones could help the tugboat stop closer to the dock.

▶ What kinds of materials do you think we could use for our dock cushions?

- *We could try using some soft objects in the classroom, like the whiteboard eraser.*
- *We could look through the art supplies to see if there's anything in there we could use.*

Draw students' attention to the four dock cushion testing stations. Gather students around one of the stations, and remind them that the Hall's car represents a tugboat and the bin represents a dock. Then introduce the materials they can use to make their cushions: cotton balls, craft sticks, medium wedge erasers, modeling clay, rope, and sponges.

Explain to students that they will work in groups to test the different materials so that they can then choose which materials to use for their group's cushion.

Have students Think–Pair–Share in response to the following question.

▶ How can we test the materials to see which ones will help the tugboat stop closer to the dock?

- *We could put them in front of the dock and make the tugboat bump into them.*
- *We can see how far the tugboat bounces after it hits the materials.*

Invite two student volunteers to help demonstrate how to record the results of a test. Without inserting a cushion, follow the procedure (Lesson 17 Resource F) three times. Record the result each time by marking a sticky note with the color of the zone where the front of the tugboat stops. Begin a results chart by placing these three sticky notes on the board in a column. Leave enough space to the right of the sticky notes for six additional columns. Label this first column No Cushion. Remind students that if the tugboat stops close to the dock, its front will be in the green zone; if it stops a little farther away from the dock, its front will be in the yellow zone; and if it stops far away from the dock, its front will be in the red zone.

Teacher Note

If students suggest other materials and sufficient supplies are available, consider including these materials as options for students to test and use for the remainder of the Engineering Challenge. Lesson 17 Resource F provides additional material ideas.

Teacher Note

Consider forming groups of about three students and assigning two groups to each of the four stations. Each group can test one of the two materials available at the station.

Differentiation

Later in this lesson, groups will post sticky notes with their results on a class results chart. To support students with color vision deficiencies, consider designating a shape for each of the three colors. For example, students can draw green circles, yellow triangles, and red squares on their sticky notes.

Teacher Note

See the end of this section for a sample results chart.

Then instruct a third student volunteer to carefully hold one of the Imagine stage testing bags against the dock so that the tugboat will hit the bag without hitting the student's fingers. With the bag in place, follow the procedure (Lesson 17 Resource F) three more times, marking a sticky note with green, yellow, or red to record the result each time. Demonstrate for students that they should attach their three sticky notes to the bag of materials.

Place students in groups. Explain that two groups will share each testing station and that each group will test one of the two materials at their station. Then assign each group to one of the four stations.

Tell students to look at the materials at their station. Ask them to predict how using each material as a dock cushion will affect the movement of the tugboat.

Sample student responses:

- *Cotton balls are really soft, so I think they will only make the tugboat bounce a little bit.*
- *I think the clay will keep the tugboat from bouncing back because it's squishy.*

Tell students that they are now ready to start testing their material. Remind students that they need to test their material three times, and distribute three sticky notes and a red, yellow, and green marker to each group. Instruct groups to begin, and circulate to provide support.

Invite groups that finish early to carry out more than three tests on their material or to trade materials with the other group at their station.

After all groups have completed their three tests, bring the class back together, and tell students that they will share their results.

Add six columns to the results chart, and attach one of the six illustrations (Lesson 18 Resource) to the header of each column.

Point to the first material on the results chart. Ask the group or groups that tested that material to post their sticky notes below the material's illustration on the chart. Repeat this process for the remaining five materials.

Teacher Note

Before students begin testing, discard these three sticky notes so that students may independently test the bag of materials from this demonstration.

Spotlight on Crosscutting Concepts

Designing and conducting simple tests can provide students with evidence that they can use to inform their ideas about causes and effects (CC.2).

Students use the results from these tests to decide which materials would be most effective for stopping the tugboat close to the dock.

Teacher Note

To support collaboration, consider designating three roles for testing materials: One student holds the bag in place, a second student releases the tugboat, and a third student marks the sticky note to record the result. Students can switch roles for each test.

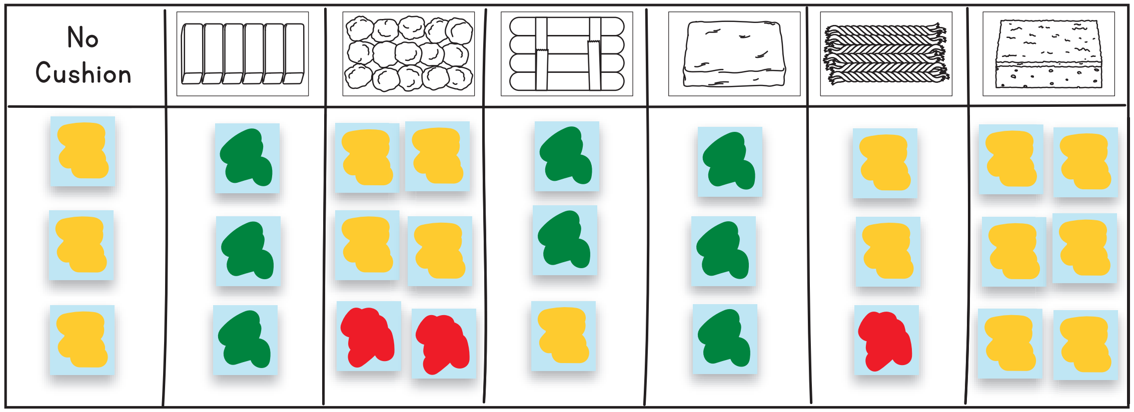
Teacher Note

Keep this results chart on display until the end of the Engineering Challenge.

Teacher Note

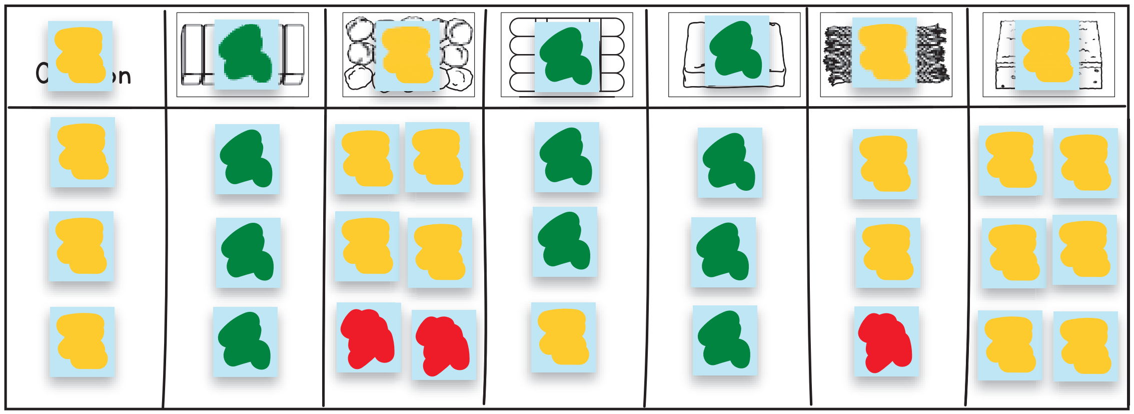
Actual results may differ from those in the sample shown below.

Sample class chart:



Next, analyze the results with students to designate a single color zone for each material. Start by pointing to the first material on the results chart. Ask the class to look at the results and to decide on the color zone for this material: green, yellow, or red. If students need support, work with them to count how many green sticky notes, yellow sticky notes, and red sticky notes are in the column. Then suggest selecting the most frequent result from all three or six tests. After the class has determined the color zone for each material, mark a sticky note with that color, and attach the sticky note to the illustration of the material.

Sample class chart:



Teacher Note

If the results for a material include one of each color, classify that material as yellow.

▶ **Which materials do you think will make the best cushion? Why do you think so?**

- *I think the craft sticks will make the best cushion because the tugboat didn't bounce that much with them.*
- *I think the clay will make the best cushion because the tugboat only bounced to the green zone when we used it.*

▶ **If the tugboat stopped in the same color zone with two different materials, how do we know which material worked better?**

- *We could look at where on that color the tugboat stopped.*
- *Maybe we can measure how far the tugboat goes in a color zone.*

Highlight the importance of measuring with numbers to compare the distance the tugboats bounce back, and tell students that they will use a new measuring paper when they test their cushions.

Teacher Note

When students test their cushions during the Create stage in Lesson 19, use the lined measurement paper (Lesson 19 Resource), which includes lines and numbers so students can measure distance within each color zone.

Plan Dock Cushions 7 minutes

Tell students that after engineers imagine a possible solution, they are ready to start planning. Return to the engineering design process visual, and move the sticky note or magnet to mark the Plan stage. Remind students that during the Plan stage engineers decide which materials to use, and they draw or make models of their ideas.

Explain to students that each group will work together to plan a dock cushion. Point out to students that they can either use one material or combine materials to make their cushions. Allow groups time to discuss the different materials and to decide which ones they want to use.

Check for Understanding

Call out the materials that students tested, one by one. Ask students to give a thumbs-up if they think the material will make a good cushion, a thumbs-down if they think the material will make a bad cushion, and a thumbs-to-the-side if they are unsure or if they think the cushion will be somewhere in the middle. For each material, ask one or two students to share their reasoning with the class.

Listen for responses that mention how well each material might work to solve the problem (SEP.3) by causing the tugboat to travel a shorter distance after the bump (CC.2, PS2.B).

Differentiation

Students who need support articulating their ideas and coming to a consensus may find these sentence frames helpful:

- I think we should use _____ because _____.
- What if we try _____?
- I agree because _____.
- I disagree because _____.

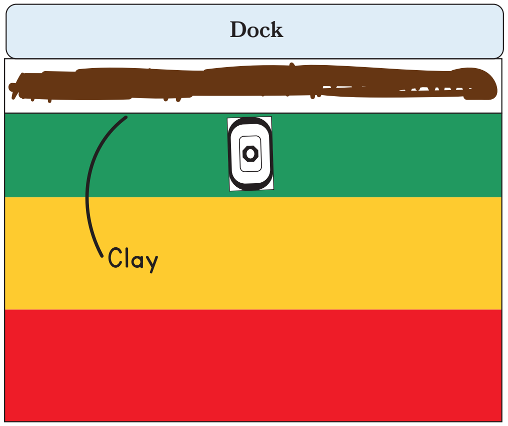
Teacher Note

If students in a group struggle to agree on a plan, tell them that they will have the opportunity to change their cushion during the Improve stage of the engineering design process.

Have students record their plans in their Science Logbooks (Lesson 18 Activity Guide). First, instruct students to draw their cushion in the white box below the blue box labeled Dock. Encourage students to try to write the name of the material or materials near their drawing. Then have students imagine that a tugboat is moving from the bottom of the page, crossing the three color zones, and bumping into the dock, just as students observed when they tested materials at the Dock Cushion Testing Station. Tell students to predict where the tugboat will stop after it hits their cushion.

Distribute a small tugboat cutout (Lesson 10 Resource B) to each student, and have students glue the cutout in the zone where they think the tugboat will stop.

Sample student response:



Check for Understanding

Students draw their plans for using the materials the class tested to make their dock cushions. Then students predict how their cushions will affect the movement of the model tugboat.

Elements Assessed	
SEP.6: Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem. ETS1.B: Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. CC.2: Simple tests can be designed to gather evidence to support or refute student ideas about causes.	
Evidence	**Next Steps**
Students draw a cushion they plan to build to stop the tugboat closer to the dock. Students select materials for their design to solve this specific problem (SEP.6, ETS1.B).	If students select only materials that did not test well, allow them to move forward with testing, but encourage them to use the class results chart to inform their material selections during the Improve stage in Lesson 19. If students draw a material the class did not test, coach them to think about the testing the class did in the Imagine stage, and help them select materials that tested well.
Students glue their tugboat cutout closer to the dock than the model tugboat stopped during the demonstration without a cushion. By predicting that the tugboat will stop closer to the dock, students exhibit an awareness that their cushion should cause the tugboat to bounce back less than it would without their cushion present (CC.2).	If possible, follow up with students about their predictions. Ask students to explain why they think their cushion will help solve the problem. Consider using the following sentence frame to support their thinking: I predict that our tugboat will stop _____ (far from/close to/very close to) the dock. The reason I think so is that _____.

Land 3 minutes

Draw students' attention to the Imagine and Plan stages on the engineering design process visual. Point to the Imagine stage, and remind students that during this stage engineers explore materials and brainstorm possible solutions. Point to the Plan stage, and remind students that during this stage engineers decide which materials they will use and create a drawing or a model of their solutions.

Have students Think–Pair–Share about what they did during the Imagine stage.

Sample student responses:

- *We tested different materials and looked at how far the tugboat bounced.*
- *We looked at the colors from all the tests to see which materials worked better than others.*

Then have students Think–Pair–Share about what they did during the Plan stage.

Sample student responses:

- *We talked in our groups and picked materials we want to use.*
- *We drew our idea for our cushion.*

Tell students that they will get to create their cushions in the next lesson.

Lesson 19

Objective: Apply the engineering design process to create a model cushion that helps a tugboat stop close to a dock.

Agenda

Launch (3 minutes)

Learn (27 minutes)

- Create Dock Cushions (5 minutes)
- Test Dock Cushions (10 minutes)
- Improve Dock Cushions (12 minutes)

Land (5 minutes)

Launch 3 minutes

Show students the lined measurement paper (Lesson 19 Resource). Point out that the boxes match up with the numbers, and count the rows from 1 to 11 with the class. Emphasize that boxes 1, 2, and 3 are in the green zone; boxes 4, 5, 6, and 7 are in the yellow zone; and boxes 8, 9, 10, and 11 are in the red zone. Tell students that when the tugboat stops twice in the same color zone, they can use the boxes to figure out which time the tugboat stopped closer to the dock.

Gather students around the testing station, and invite two volunteers to help demonstrate how to measure the distance that the tugboat bounces without a dock cushion. Follow the testing station procedure (Lesson 17 Resource F). Then demonstrate how to measure the distance from the dock to the front of the tugboat by counting the number of boxes in front of the tugboat, including the box that the front of the tugboat is in. Record the result for use in the next lesson. Tell students that they will use the stations to test their cushions later in this lesson.

Teacher Note

Plan to support groups during testing to ensure that students measure the bounces accurately and become more comfortable with numbers.

Learn 27 minutes

Create Dock Cushions 5 minutes

Display the engineering design process visual (Lesson 17 Resource C), and tell students that in this lesson they will focus on the Create and Improve stages of the engineering design process. Move the sticky note or magnet to mark the Create stage, and remind students that in this stage engineers use their plans to build their solution.

Have students review the plans they recorded in their Science Logbooks (Lesson 18 Activity Guide). Explain to students that they will create their dock cushions by filling snack bags with the materials they chose. Place students in their groups, distribute a snack bag to each group, and show students the materials that the class will share. Then tell groups that they should create their cushion by filling their bag with materials. As students assemble their cushion, visit groups to discuss their choices and predictions.

- ▶ Why did you choose this material?
- ▶ When you add your cushion, where do you think the tugboat will stop? Why?

Test Dock Cushions 10 minutes

Revisit the class problem and solution chart, and explain that engineers need to test the solutions they create to find out whether they work.

Review the testing process with the class: One student holds the cushion against the dock (while keeping fingers away from where the tugboat will hit), one student releases the tugboat from the mark on the ramp, and one student counts the number of boxes between the cushion and the front of the tugboat (including the box that the front of the tugboat is in) and announces the number for the group to record.

Teacher Note

As suggested in Lesson 17 Resource F, consider distributing predetermined amounts of materials to each group to encourage sharing.

Spotlight on Three-Dimensional Integration

In this lesson, students gain experience solving problems through engineering (ETS1.A). Students recognize that when objects bump, the objects push on one another, which can change their movement (PS2.B). From simple tests, students gather evidence that the material the tugboat bumps into determines how the tugboat moves (CC.2). Students use this information to design a possible solution to a problem (SEP.6). Then they use counting and numbers to analyze data from testing to determine whether their designs work as intended (SEP.5).

Have students open to the Create and Improve section of their Science Logbooks (Lesson 18 Activity Guide), and direct students' attention to the collection of materials in the first row under Materials. Tell students to circle the material or materials their group used to make their cushion. Then point out the three empty boxes in the same row, under Bounce. Explain to students that they will write a number in each box to show how far the tugboat bounces in each of their three tests. Tell students that they will have a chance to create and test at least one more cushion later in the lesson.

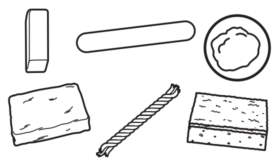
Remind students that they can switch jobs between each of their three tests. Then assign groups to testing stations, and if necessary, specify which group at each station will test their cushion first.

As groups test their cushions, circulate to assist each group and to ask questions such as the following:

- Does this cushion help the tugboat?
- How can you tell whether this cushion helps the tugboat?

Remind students to record in their Science Logbooks (Lesson 18 Activity Guide) how far the tugboat bounces after each test.

Sample student response:

Materials		Bounce		
1		*5*	*7*	*4*

Differentiation

To help students count boxes on the measurement paper and compare their results, consider providing tools and manipulatives, such as number lines, counting bears, linking cubes, or 10-frames.

To support students who are not yet writing their numbers, write the numbers 1–11 within each empty square on the Science Logbook page, and have students circle their results instead.

Check for Understanding

Make sure that students accurately count and use numbers to observe and record how far the model tugboat bounces from the dock (SEP.5). Students should describe the effects of their cushion (CC.2) and recognize that their cushion can change how far the tugboat bounces from the dock (PS2.B).

Improve Dock Cushions 12 minutes

After groups have completed three tests of their first dock cushion, bring the class back together. Return students' attention to the engineering design process visual (Lesson 17 Resource C), and move the sticky note or magnet to mark the Improve stage. Explain that during the Improve stage engineers try to make their solutions better.

Invite students to think about their results as well as ways they could improve their cushion. Then instruct students in each group to work together to adjust their cushion. Circulate to support students and to ask questions such as the following:

- What happened when you tested your cushion?
- Which other material are you thinking of trying?
- Why do you think that material could help you solve the problem?

Allow groups time to complete three tests on each of up to two additional versions of their cushion. After groups finish their final tests, direct students' attention to the last row they completed in their Science Logbooks (Lesson 18 Activity Guide). Have students circle the lowest number in that row to indicate the shortest distance that their final cushion pushed the tugboat away from the dock.

Teacher Note

If students have difficulty brainstorming ways to improve their cushion, encourage them to manipulate materials, combine materials, or add more of a material they used to create the first version of their cushion.

If students successfully stopped the tugboat in the green zone in all three tests with the first version of their cushion, challenge students to stop the tugboat even closer to the dock.

Check for Understanding

Listen for explanations that include students' rationale for making specific changes to solve the tugboat's problem (SEP.3). Students should only make adjustments that they think will help the tugboat stop closer to the dock (CC.2, PS2.B).

If students have trouble identifying ways they might improve their cushion, ask them the following questions to prompt them to focus on solving the problem:

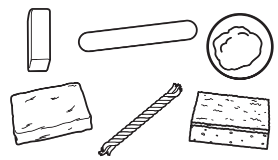
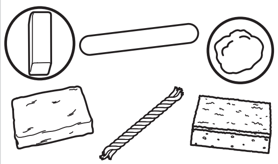
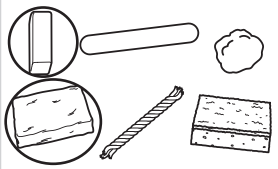
- How can you make the tugboat stop closer to the dock?
- Which materials do you think will work best?

Consider referring students to the results chart from Lesson 18 to help them identify the materials that are likely to improve their cushion the most.

Content Area Connection: Mathematics

To select the number that shows the smallest bounce the materials produced, students must compare numbers between 1 and 11 presented as written numerals (CCSS.Math.Content.K.CC.C.7).

Sample student response:

Materials		Bounce		
1		*5*	*7*	*4*
2		*2*	*3*	*3*
3		*2*	*1*	*2*

Prompt students to clean up their workspace.

Teacher Note

In the next lesson, students share their final dock cushions with the class. Between lessons, store each group's cushion in a place that is out of the way. Consider labeling each cushion with a sticky note with students' names or assigning groups a number with which to label their cushion.

Land 5 minutes

Bring the class back together. Remind students that during the Improve stage engineers make changes to try to make their solutions better. Ask students to consider what they did to improve their dock cushions.

▶ What did you keep the same? What did you change?

- *We kept one material the same but added another material on top.*
- *We had craft sticks and added a sponge behind it.*

Then ask students to use a nonverbal signal to indicate whether their changes caused their cushions to work better.

▶ How do you know whether your cushion worked better or worse than before?

- *We know our cushion got worse after we made changes because the tugboat bounced to 4 instead of to 2.*
- *The tugboat only bounced to 1 after we added craft sticks to the cotton balls, so our cushion worked better.*

▶ Did your cushion solve the problem?

- *Yes, our cushion helped the tugboat stop closer to the dock.*
- *At first, our cushion made the tugboat bounce about the same as it did without a cushion. But then we improved our cushion, and the tugboat bounced less.*

Tell students that in the next lesson they will move to the final stage of the engineering design process, the Share stage.

Content Area Connection: Mathematics

When students consider their cushion's performance before and after making changes, they directly compare measurable attributes to see which design has "less of" that attribute (CCSS.Math.Content.K.MD.A.2). For example, students identify which of their designs caused the tugboat to bounce back fewer boxes.

Teacher Note

Encourage students to discuss their results openly and proudly, regardless of how their cushions performed. An unsuccessful solution offers valuable insight into what works best in a given situation.

Lesson 20

Objective: Apply the engineering design process to create a model cushion that helps a tugboat stop close to a dock.

Agenda

Launch (3 minutes)

Learn (27 minutes)

- Share Dock Cushions (10 minutes)
- Analyze Data (12 minutes)
- Examine Dock Cushion Examples (5 minutes)

Land (5 minutes)

Launch 3 minutes

Return to the engineering design process visual (Lesson 17 Resource C), and move the sticky note or magnet to mark the Share stage. Explain that in the Share stage engineers present their work and learning to others. Tell students that in this lesson they will share their dock cushions with the class.

Learn 27 minutes

Share Dock Cushions 10 minutes

Explain to students that they will have a chance to see the dock cushions other groups created and to find out how well other groups' cushions worked. Ask groups to gather their final dock cushion from the previous lesson. Then have each group display their cushion and Science Logbooks (Lesson 18 Activity Guide) on their tables or desks.

Review with students the classroom rules for a Gallery Walk. Then invite groups to move around the room to view the cushions that the other groups created. As groups look at their classmates' cushions, ask students how each cushion helps the tugboat stop closer to the dock and whether the cushion gives them new ideas.

Analyze Data 12 minutes

Have groups collect their dock cushions and Science Logbooks. Then bring the class back together, and explain to students that they will now compare all their results. On a flat surface that all students can see, start a line plot by placing 11 sticky notes in a row and labeling them 1–11. Tell students that they are going to sort their cushions. Explain to students that on one end they will place the cushions that helped the tugboat stop closest to the dock, and on the other end they will place the cushions that pushed the tugboat farthest away from the dock.

Ask students whether they remember how many boxes the class counted after the tugboat bumped into the dock without a cushion. Label another sticky note No Cushion, and place the sticky note under the number that captures how far back the tugboat moved without a cushion in place.

Then invite groups to place their cushion under whichever number they circled in their Science Logbooks (Lesson 18 Activity Guide) for that cushion. Ask students to Think–Pair–Share about what they notice when they look at where all the groups placed their cushions.

Sample student responses:

- *Most of the groups made a cushion that helped the tugboat stop closer to the dock.*
- *The cushions with clay and erasers worked really well.*

▶ How did using numbers help you decide which materials worked better than others?

- *We just counted the boxes and wrote the numbers. That made it easy to see which materials worked better.*
- *When two materials bounced the tugboat into the yellow zone, the numbers helped us tell which one bounced it farther.*

Content Area Connection: English

Consider explaining to students that they can use the word *cushion* as both a noun and a verb. For example, tell students that they made cushions (noun) to cushion (verb) the bump between the tugboat and the dock. Students may enjoy learning how they can use other words from the Engineering Challenge, such as *dock* and *board*, as nouns and verbs as well (CCSS.ELA-Literacy.L.K.4.A).

Differentiation

To help students recognize the connection between the results they are analyzing and the experience of testing their cushions, consider color-coding the sticky notes or numbers to match the color zones on the Dock Cushion Testing Station measurement paper.

Extension

If multiple classrooms participate in the Engineering Challenge, consider sharing and comparing data across classes.

▶ Which material do you think works best for a dock cushion? Why? ☑

- *I think clay works best because the groups that used clay had a bounce of 1 or 2.*
- *I think erasers work best. They made the tugboat stop closer to the dock than the other materials.*

Examine Dock Cushion Examples 5 minutes

Display the photographs of dock cushions (Lesson 20 Resource), and tell students that these are real examples of cushions that people use on docks.

Check for Understanding

Listen for responses that mention numerical patterns in the data (CC.1, SEP.5). Students should recognize that the data show how each cushion changed the movement of the tugboat (PS2.B), and students should use the data to explain which cushions best solved the problem (ETS1.A).

▶ What do you notice about these cushions?

- *I notice that some of them look like rubber or something else that's soft.*
- *I notice that each cushion looks different. One looks like a big balloon.*

▶ How are these cushions similar to your cushions? How are they different?

- *Our cushion has soft materials, just like some of the ones in the pictures.*
- *Our cushions are smaller and not as strong because they are models.*

Land 5 minutes

Remind students of the tugboat captain who was in a hurry and the Phenomenon Question **How can we help a tugboat stop close to a dock?**

▶ How did you use your knowledge of pushes and pulls to help the tugboat captain?

- *We know that when a tugboat bumps into a dock, the dock pushes on the tugboat. That's why the tugboat bounces away.*
- *We know that weaker pushes can't move objects as far as stronger ones can, so we made the push from the dock feel weaker.*

▶ How did your cushion help the tugboat stop closer to the dock?

- *Our cushion made the push from the dock feel weaker.*
- *Our cushion gave the tugboat a softer push than the dock did without a cushion.*

Summarize that students' cushions successfully solved the Engineering Challenge by causing the tugboat to stop closer to the dock than it did when no cushion was present.

Lessons 21–23
Tugboats Moving Cargo Ships

Prepare

In Lessons 21 through 23, students synthesize their learning from throughout the module and express their understanding of how tugboats use pushes and pulls to move cargo ships in a Socratic Seminar and an End-of-Module Assessment. In Lesson 21, students discuss the Essential Question in a Socratic Seminar and reflect on how they built their knowledge during the module. Lesson 22 introduces students to a new phenomenon, games at a carnival. Students then complete the End-of-Module Assessment, which is based on that phenomenon. During the End-of-Module Assessment, students engage in Science and Engineering Practices (SEP.3, SEP.4), apply the lens of Crosscutting Concepts (CC.2, CC.3), and use their knowledge of Disciplinary Core Ideas (PS2.A, PS2.B, PS3.C) to explain how people use pushes and pulls to play carnival games. In Lesson 23, this module's culminating lesson, students debrief the assessment and reflect on how they built their knowledge throughout the module by understanding and applying the Crosscutting Concept of Cause and Effect.

Application of Concepts

Tasks

Socratic Seminar

End-of-Module Assessment

Essential Question

How do tugboats move cargo ships through a harbor?

Phenomenon Question

How do people use pushes and pulls to play carnival games?

Student Learning

Knowledge Statement

Pushes and pulls can cause objects to start moving and can cause their movement to change.

Objectives

- Lesson 21: Explain how tugboats use pushes and pulls to help move cargo ships. (Socratic Seminar)
- Lesson 22: Explain how people use pushes and pulls to play carnival games. (End-of-Module Assessment)
- Lesson 23: Explain how pushes and pulls can start, stop, or change the direction of an object's movement. (End-of-Module Debrief)

Standards Addressed*

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. (Demonstrating)

K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull. (Demonstrating)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP.8: Obtaining, Evaluating, and Communicating Information ▪ Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.	PS2.A: Forces and Motion PS2.B: Types of Interactions PS3.C: Relationship Between Energy and Forces	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns. *Connections to Nature of Science* Science Addresses Questions about the Natural and Material World ▪ Scientists study the natural and material world.

* This section lists the Performance Expectations, Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts students may apply during instructional activities in these lessons. See the End-of-Module Assessment rubric for a list of standards the assessment addresses.

Materials

		Lesson 21	Lesson 22	Lesson 23
Student	Key term card (1)	●		
	New York Harbor Knowledge Deck card (1)	●		
	End-of-Module Assessment		●	
Teacher	New York Harbor Knowledge Deck poster	●		
	Carnival Game Photographs (Lesson 22 Resource)		●	
	Crosscutting Concept Cause and Effect card (1)			●
Preparation	Prepare key term cards. (See Lesson 21 Resource.)	●		
	Cue duck-catching game video and balloon dart game video: http://phdsci.link/1593 and http://phdsci.link/1594.		●	●
	Cue golf ball stopping video and golf ball changing direction video: http://phdsci.link/1614 and http://phdsci.link/1615.		●	
	Score End-of-Module Assessment and write individual feedback.			●
	Select at least one End-of-Module Assessment item for the class to debrief, and prepare a sample response for that item to share with students.			●
	Prepare Crosscutting Concept Cause and Effect card. (See Lesson 23 Resource.)			●
	Select student work products that show evidence of three-dimensional learning, and display them in different areas of the classroom. Student work products may include the anchor model, class charts, selected Science Logbook pages, and Engineering Challenge designs.			●

Lesson 21

Objective: Explain how tugboats use pushes and pulls to help move cargo ships. (Socratic Seminar)

Agenda

Launch (7 minutes)

Learn (20 minutes)

- Prepare for Socratic Seminar (5 minutes)
- Engage in Socratic Seminar (15 minutes)

Land (8 minutes)

Launch 7 minutes

Tell students that they will participate in a Link Up routine to identify relationships, or connections, between key terms they learned throughout the module. Ask for a few volunteers to model the routine. Distribute a different key term card (Lesson 21 Resource) to each volunteer, and read aloud each term. Describe the routine to the class, explaining each step while guiding the volunteers through one round. Have volunteers complete a few additional rounds. Point out that terms can relate to each other in different ways.

Next, distribute key term cards to the rest of the class so each student has a card. While handing out the cards, make sure to read aloud each term. Prompt students to circulate and find a partner with a different, but related, key term card. Ask students to discuss the following question with their partner.

▶ How do these words relate?

Continue the routine until students have had the opportunity to discuss their key terms with a few other students. After the routine, invite partners from the final round to share their key terms with the class and to explain how the terms are related.

Differentiation

Before using the Link Up routine with key terms, consider having students practice with familiar words such as *ball*, *toy car*, *throw*, and *roll*. Highlight connections between these familiar words to help students understand the different ways terms can be related.

Learn 20 minutes

Prepare for Socratic Seminar 5 minutes

Display the photograph on the front of the New York Harbor Knowledge Deck poster. Remind students of the Essential Question: **How do tugboats move cargo ships through a harbor?** Ask students to think about what they have learned since they first observed the photograph and how their answer to the Essential Question has changed.

Tell students they will share their current understanding of the Essential Question with one another through a Socratic Seminar discussion. Review the routines and expectations for participating effectively in a Socratic Seminar, including classroom guidelines and resources for speaking and listening. Explain that students can refer to the anchor model, the anchor chart, and other classroom resources to support their discussion. Then display and read aloud the Essential Question: **How do tugboats move cargo ships through a harbor?** Ask students to prepare for the seminar by briefly discussing the question with a partner.

Engage in Socratic Seminar 15 minutes

Divide the class into groups, and instruct students in each group to sit in a circle. Read aloud the Essential Question to begin the Socratic Seminar discussion. Have students discuss their answers to the Essential Question with their group. Allow students to respond to one another directly, with minimal teacher facilitation. Students should remind one another of conversation norms, ask for evidence, and pose questions to extend the conversation. As needed, step in briefly to reinforce norms for collaborative conversations. If students' conversation wanes or wanders, consider asking one of the following questions to stimulate additional conversation:

- How does a tugboat use pushes and pulls to help move a cargo ship?
- How does a tugboat make a cargo ship move faster?
- How does a tugboat change the direction of a cargo ship?
- How does a tugboat make a cargo ship slow down and stop?

Content Area Connection: English

The Socratic Seminar allows students to use their speaking and listening skills to express and deepen their science content knowledge. In a Socratic Seminar, students participate in a collaborative, evidence-based, academic conversation. In this discussion, students should work toward grade-level expectations for collaborative conversations (CCSS.ELA-Literacy.SL.K.1). See the Socratic Seminar resource in the Implementation Guide for more background.

Check for Understanding

As students engage in the Socratic Seminar, note how they provide details about scientific ideas and practices (SEP.8). To monitor student participation and the flow of the conversation, consider writing each student's name around the edge of a sheet of paper before the lesson and drawing lines between speakers during the conversation.

Teacher Note

Depending on students' familiarity with Socratic Seminars, consider adding some of these supports to the seminar.

- Students use sentence frames to help them build on one another's remarks.
- Students use talking chips. Each student receives a chip. After a student shares, the student places the chip in the middle of the circle. After every student shares and all chips are in the circle, students retrieve the chips and start the process again.

▶ How do stronger pushes affect an object's movement? How do weaker pushes affect an object's movement?

▶ How can pushes and pulls turn an object?

▶ What happens when two objects bump into each other?

Land 8 minutes

Restate a few responses from the Socratic Seminar that show evidence of students' learning. Ask students to reflect silently on how their knowledge has grown since the beginning of the module.

▶ You have learned a lot about how tugboats move cargo ships. What did you do to build your knowledge?

Model how to find a student work product (e.g., a page from a Science Logbook or a class chart) that shows evidence of how students built their knowledge during the module. Explain the difference between how students learned and what they learned. Instruct students to find one work product in their Science Logbooks or elsewhere in the classroom that shows evidence of how they learned. Have students compare how they learned with a partner who chose a different work product.

▶ What did you do in this work?

- *(Response comparing Lesson 4 push and pull chart with Lesson 5 Activity Guide) In one lesson, we grouped how we moved each toy into pushes and pulls. In the other lesson, we drew the teacher pulling an object.*
- *(Response comparing Lesson 7 Activity Guide with Lesson 11 Activity Guide) In one lesson, we showed how a stronger push made the ball move faster. In the other lesson, we showed where we put the tugboats to make the cargo ship turn.*

Teacher Note

Display the driving question board, anchor chart, and anchor model to help students reflect on how their knowledge has grown.

Differentiation

To provide additional support, assign student pairs specific work products that demonstrate clear evidence of similarities in the learning process, such as products in which students applied the same Science and Engineering Practice. For example, consider pairing these work products:

- Lesson 4 push and pull chart and Lesson 5 Activity Guide
- Lesson 7 Activity Guide and Lesson 11 Activity Guide
- Lesson 10 Activity Guide and Lesson 13 Activity Guide

▶ What is the same about what you did? What is different?

- *(Response comparing Lesson 4 push and pull chart with Lesson 5 Activity Guide) Both times, we had to choose between pushes and pulls. In the first lesson, we looked at a lot of pushes and pulls with the toys. But in the other lesson, we only saw a pull happen.*
- *(Response comparing Lesson 7 Activity Guide with Lesson 11 Activity Guide) We showed how pushes move objects both times. In the first lesson, we showed how pushes made the ball move forward. But on the map in our Science Logbooks, we showed how we used pushes to turn the cargo ship.*

Restate several student responses that relate to the Science and Engineering Practices. Explain to students that science practices are actions scientists take to learn about the world and gather evidence to develop scientific ideas. Select a student response and explain how it relates to one of the practices. Ask students to share other experiences they have had with using this practice, such as in other modules or outside of school. Help students identify how they used the practice to build knowledge of phenomena or to develop scientific ideas. Tell students they can continue to use science practices to understand the world around them.

Teacher Note

Depending on student responses, this discussion may focus on actions related to specific elements of a Science and Engineering Practice (e.g., measuring, which relates to SEP.3 and SEP.5) or, more broadly, on a few of the eight Science and Engineering Practices (e.g., SEP.3: Planning and Carrying Out Investigations).

Spotlight on Three-Dimensional Integration

Throughout *PhD Science*®, students apply all three dimensions of the NGSS in concert to make sense of phenomena. This activity highlights the role of Science and Engineering Practices in students' three-dimensional learning throughout the module. This discussion should not isolate Science and Engineering Practices; rather, it should help students reflect metacognitively on links between phenomena, ideas, concepts, and practices in science and engineering.

Lesson 22

Objective: Explain how people use pushes and pulls to play carnival games. (End-of-Module Assessment)

Agenda

Launch (5 minutes)

Learn (28 minutes)

- Complete End-of-Module Assessment (28 minutes)

Land (2 minutes)

Launch 5 minutes

Tell students that in this lesson they will apply their understanding of how pushes and pulls can move objects to a carnival setting in an End-of-Module Assessment. Explain that the assessment is a way for students to show all the knowledge they have developed throughout the module.

First, ask students to show with a nonverbal signal whether they have ever played a game at a carnival, fair, or amusement park. Ask one or two volunteers to share what they know about carnival games. Then show the class the videos of children playing carnival games (http://phdsci.link/1593 and http://phdsci.link/1594).

Engage students in a discussion about the videos.

▶ What are the children in each video doing?

- *In one video, kids are catching toy ducks with nets.*
- *The boys were throwing darts at the balloons.*

▶ Are the children using pulls to play either game? Are they using pushes?

- *They pulled the ducks out of the water.*
- *I think throwing a dart is a push because the dart moves away.*

Teacher Note

To help students recognize that a throw is a push, ask the class to think about whether the darts moved away from the children in the second video.

▶ Do these videos remind you of anything that we did in our science lessons?

- *The kids use pushes and pulls to move objects just like we did.*
- *I think the boys throwing darts is kind of like when we pushed the toys across the paper.*

▶ How are these games different from what we did in our science lessons?

- *We didn't use the same toys as the kids in the videos.*
- *Our lessons were mostly about tugboats and cargo ships.*

Acknowledge that these games are different from the activities that students have engaged in throughout the module, but also highlight responses that mention that the carnival games involve pushes and pulls. Explain to students that they will use their learning to help them figure out how objects move in different carnival games. Introduce the Phenomenon Question **How do people use pushes and pulls to play carnival games?**

Learn 28 minutes

Complete End-of-Module Assessment 28 minutes

Distribute the End-of-Module Assessment. Explain that students will hear each assessment item read aloud, one at a time, and that students will have time to respond to each item before the class proceeds to the next item. Remind students to provide complete responses and to use the resources posted in the room. Then guide students through the End-of-Module Assessment.

Tell students to imagine they are at a carnival. Explain to students that they need to figure out how objects move in the different games. Show the class the photograph of a boat race (Lesson 22 Resource). Tell students that two children are about to play a boat race game, and point out the strings that the children are holding, which are attached to their boats. Explain that both children want to move their boats to the finish line. Direct students to item 1, and read the item aloud. Tell students to circle either *Pushes* or *Pulls* to show how they think the children should move their boats. Then tell students that the two children raced three times. Read aloud item 2, including the information in the table, and tell students to circle the child who used stronger pulls.

Next, show students the photograph of miniature golf (Lesson 22 Resource), and explain that in this game each player uses a golf club to try to hit a ball into a hole. Tell the class that to answer the next questions they will watch videos of a golf ball moving during a game of miniature golf. Play the first 7 seconds of the golf ball stopping video (http://phdsci.link/1614). Replay the clip as many times as needed. Read item 3a aloud, and tell students to circle either *Push* or *Pull* to show what they think the wall did to stop the ball. Then read item 3b aloud, and tell students to circle either *Push* or *Pull* to show what they think the ball did to the wall.

Lastly, direct students to item 4, and play the video of the golf ball changing direction (http://phdsci.link/1615). Replay the clip as many times as needed. Then read item 4 aloud, and tell students to circle either *A push* or *A pull* to show how the wall caused the ball to change direction.

Teacher Note

To prepare for the next lesson, analyze students' responses to each item on the End-of-Module Assessment and score each item on the rubric. (See the rubric and sample responses in the End-of-Module Assessment section in the Teacher Edition.) Identify at least one assessment item to debrief with the class in the next lesson. Also select an exemplar student response for the item to show students, or display the sample student response to this item from the Teacher Edition. If selecting a student response, remember to remove identifying information and to select responses from diverse students over time.

When providing individual feedback on the assessment, be sure to guide students to focus on specific areas of improvement to deepen their understanding of module concepts. Offer students who need remediation the opportunity to revisit portions of the module.

Land 2 minutes

Tell students that the next lesson will give them the opportunity to share their thinking about the End-of-Module Assessment.

Differentiation

Students with visual processing difficulties may benefit from watching both clips in this assessment at a slower playback speed.

Lesson 23

Objective: Explain how pushes and pulls can start, stop, or change the direction of an object's movement. (End-of-Module Debrief)

Agenda

Launch (3 minutes)

Learn (25 minutes)

- Debrief End-of-Module Assessment (10 minutes)
- Reflect on Crosscutting Concepts in Module Learning (15 minutes)

Land (7 minutes)

Launch 3 minutes

Explain that in this lesson students will review part of the End-of-Module Assessment and discuss their responses.

Replay the videos of the carnival games (http://phdsci.link/1593 and http://phdsci.link/1594) to remind students of the assessment phenomenon. Ask students to share questions they have about the phenomenon.

Teacher Note

In the class discussion that follows this lesson's Launch, refer to relevant student questions when discussing the End-of-Module Assessment item selected for the debrief. After the discussion, follow up with individual students to address other open questions.

Learn 25 minutes

Debrief End-of-Module Assessment 10 minutes

Tell students they will discuss part of the End-of-Module Assessment. Display the selected assessment item alongside the sample response selected in Lesson 22. Have students discuss the item by using a routine such as Inside–Outside Circles. Facilitate the discussion by posing relevant student questions from the Launch and general questions such as the following:

- ▶ What do you notice about this response?
- ▶ What do you wonder about this response?
- ▶ How does this response change your thinking?

Provide sentence frames such as the following to support students during the discussion.

- I notice _____. That makes me wonder _____.
- I notice _____. That makes me think _____.
- I used to think _____. Now I think _____.

If students' End-of-Module Assessment responses indicate the need, repeat this process with additional assessment items.

Teacher Note

Depending on students' familiarity with reflection and revision, consider these additional strategies for debriefing the assessment.

- Display a student-friendly version of the rubric's evidence description for the assessment item. Have students share evidence and questions about how the sample response meets rubric expectations.
- Display a sample response that does not meet expectations alongside the previously displayed sample response that does meet expectations. Have students compare the responses.
- Have students offer feedback on peers' responses or on their own response to the assessment item.
- Have students revise their response to the assessment item, applying new ideas from the debrief conversation to show deeper understanding in their responses.

Reflect on Crosscutting Concepts in Module Learning 15 minutes

Explain to students that scientists work to answer questions they have about the natural world, which is how scientific ideas are developed. Explain that scientists can use the Crosscutting Concepts as lenses to help them figure out answers to their questions. Point out that students have done a great deal to build their knowledge of pushes, pulls, and movement by exploring how tugboats help move cargo ships, and explain that they often used the lens of Cause and Effect to deepen their science understanding. Introduce the Cause and Effect card (Lesson 23 Resource). Explain that this

Teacher Note

Consider using a prop such as a large magnifying glass to help students understand the analogy of physically looking through a lens. In this lesson and future lessons, use this prop when students apply the lens of a Crosscutting Concept to understand a phenomenon or connect science ideas.

Spotlight on Three-Dimensional Integration

Throughout *PhD Science*, students apply all three dimensions of the NGSS in concert to make sense of phenomena. This activity highlights the role of Crosscutting Concepts in students' three-dimensional learning throughout the module. This discussion should not isolate Crosscutting Concepts; rather, it should help students reflect metacognitively on links between phenomena, ideas, concepts, and practices in science and engineering.

This lesson highlights Cause and Effect because this concept plays an especially important role in students making sense of phenomena throughout this module. Highlight connections to other Crosscutting Concepts, Disciplinary Core Ideas, and Science and Engineering Practices in the discussion as they appear.

card represents the idea that one event can make another event happen. Ask students to review examples of this concept they encountered during the module.

▶ What are some causes and effects that we noticed in our movement investigations?

- *The pushes and pulls caused toys to move.*
- *When we used a stronger push on the ball, the effect was that the ball rolled faster.*
- *We used a tugboat to pull the side of a cargo ship. That made the ship turn.*
- *To cause the cargo ship to stop, we had to use pushes or pulls.*

Select a student work product related to students' responses to this question, and model how to discuss the work product by using the lens of Cause and Effect. Then ask students to circulate to review the selected student work products displayed before the lesson. As students circulate, have them consider individually how the lens of Cause and Effect helped them understand the phenomena the work products depict. After a few minutes, have half the class stand next to a work product related to Cause and Effect. Have the rest of the class find a partner who is standing next to a work product, and instruct pairs to discuss the following question:

▶ How did the lens of Cause and Effect help you understand this phenomenon?

- *(Response related to Lesson 5 Activity Guide) We looked at how the object moved to figure out whether the cause was a push or a pull.*
- *(Response related to a dock cushion from the Engineering Challenge) We had to find the best materials for our cushions by figuring out which ones made the tugboat stop closer to the dock.*
- *(Response related to the anchor model) We could see all the ways tugboats use pushes and pulls to cause cargo ships to move through a harbor.*

Ask students to switch roles, choose different work products, and repeat this process.

After the activity is complete, select a few students to share their insights with the class. Discuss how students used the lens of Cause and Effect throughout the module to understand different phenomena. Ask students to share other phenomena that the lens of Cause and Effect helps them understand, such as phenomena from other modules or outside of school. Tell students they can continue to apply Crosscutting Concepts to answer their questions and find links between scientific ideas as they explore new situations.

English Language Development

To help English learners and other students who may need support in connecting causes with their effects, consider providing a sentence frame such as the following:

A _____ (cause) made the object _____ (effect).

Check for Understanding

Listen for students to connect the concept that events have causes that can help people identify patterns (CC.2) with other aspects of their learning throughout the module, including the phenomena they explored, the investigations they conducted, the practices they applied, and the scientific ideas they developed.

Teacher Note

Consider saving the Cause and Effect card as well as cards representing Crosscutting Concepts that students are familiar with from prior modules. Refer to relevant cards as students apply Crosscutting Concepts to make sense of phenomena in future modules.

Land 7 minutes

Draw students' attention to the driving question board, and invite them to reflect on their new knowledge and what else they would like to learn. Begin by asking students to think about questions they answered during the module. Pose questions such as these to facilitate the discussion:

- What did you do to answer these questions?
- Which answers surprised you? Why?
- Which questions relate to each other? How?

Then ask students to share new questions they have. Ask students to reflect on these new questions and the unanswered questions next to the driving question board. Pose questions such as these to facilitate the discussion:

- What do we need to know to answer this question?
- What can we do to learn more about this question?
- Does this question raise other questions?

Optional Homework

With their family's permission and supervision, students set up one of the carnival games from the End-of-Module Assessment or create their own carnival games. Students share with a family member or a friend how pushes or pulls cause objects to move in each game.

Extension

Offer opportunities for students to explore these questions, such as through shared research, collaborative investigation, or optional homework.

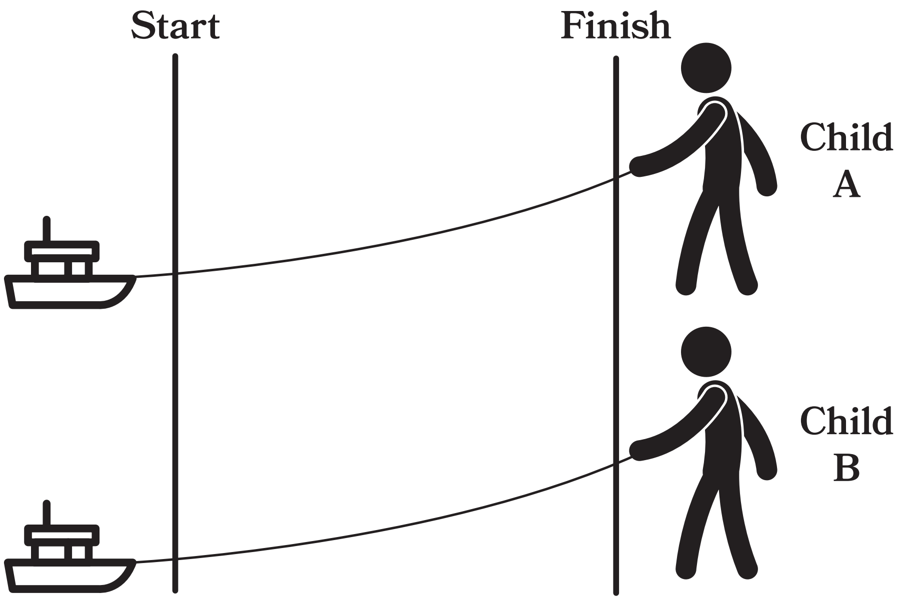
Student End-of-Module Assessment, Sample Responses, and Rubric

Name: ______________________________

LEVEL K MODULE 2

End-of-Module Assessment

1. To cause the boats to move, should the children use pushes or pulls?



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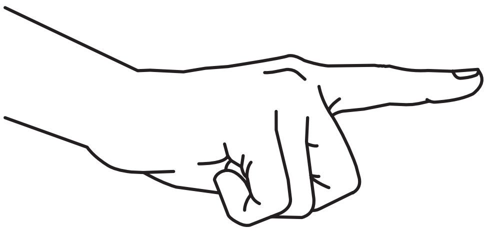
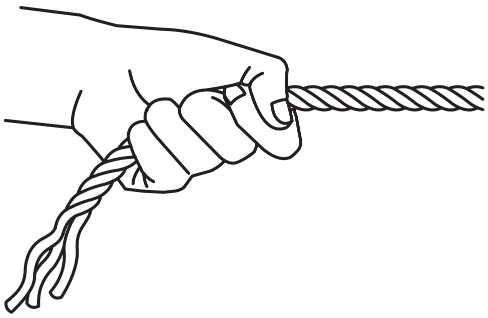


Pushes



Pulls

2. Look at the data below.

Race 1 Winner	Race 2 Winner	Race 3 Winner
Child B	Child B	Child B

Which child used stronger pulls?

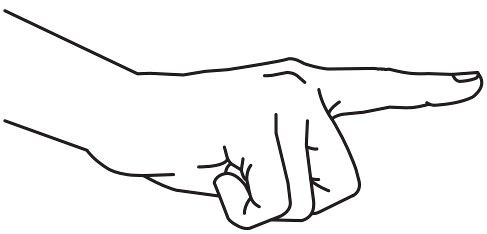
Circle.

Child A **Child B**

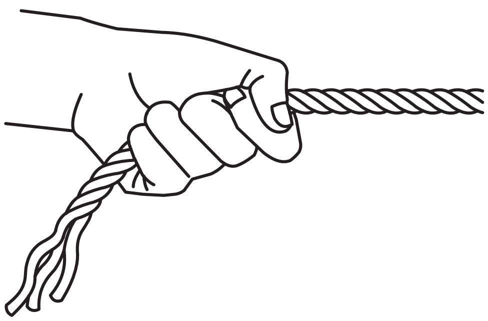
3. Watch the video.

a. Did the wall push or pull on the ball to stop it?

Circle.



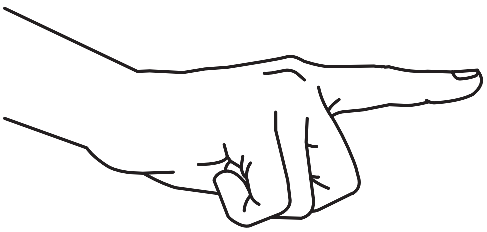
Push



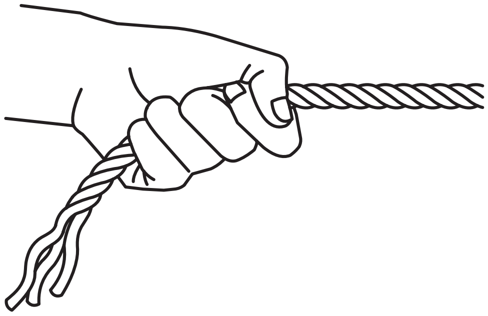
Pull

b. Did the ball push or pull on the wall?

Circle.



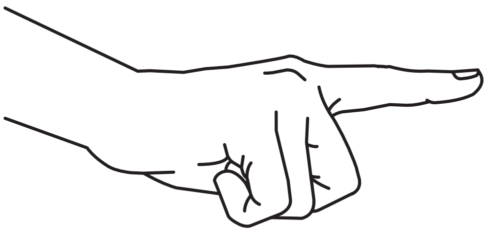
Push



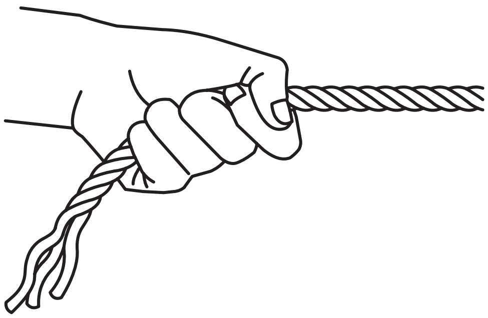
Pull

4. Watch the video. What caused the ball to change direction?

Circle.



A push



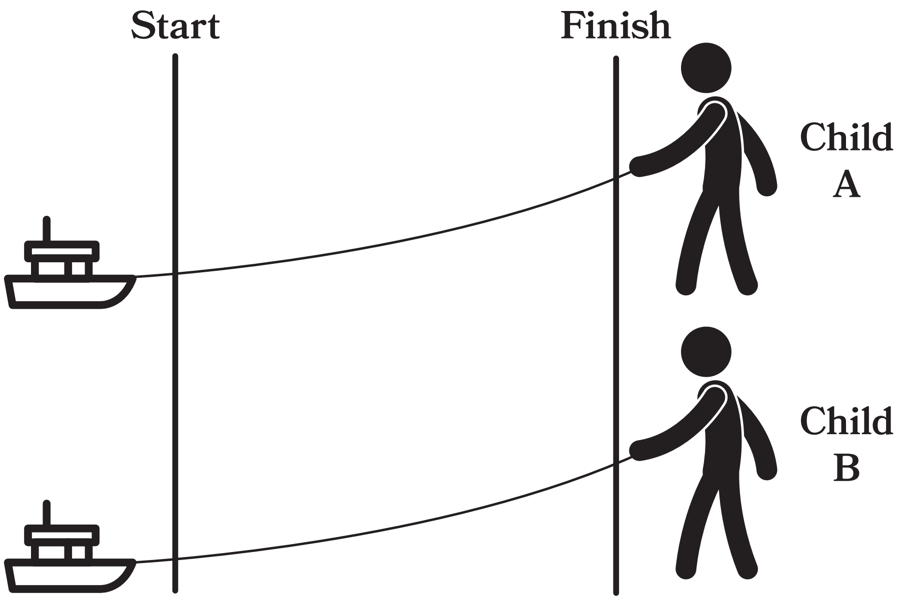
A pull

Name: Sample

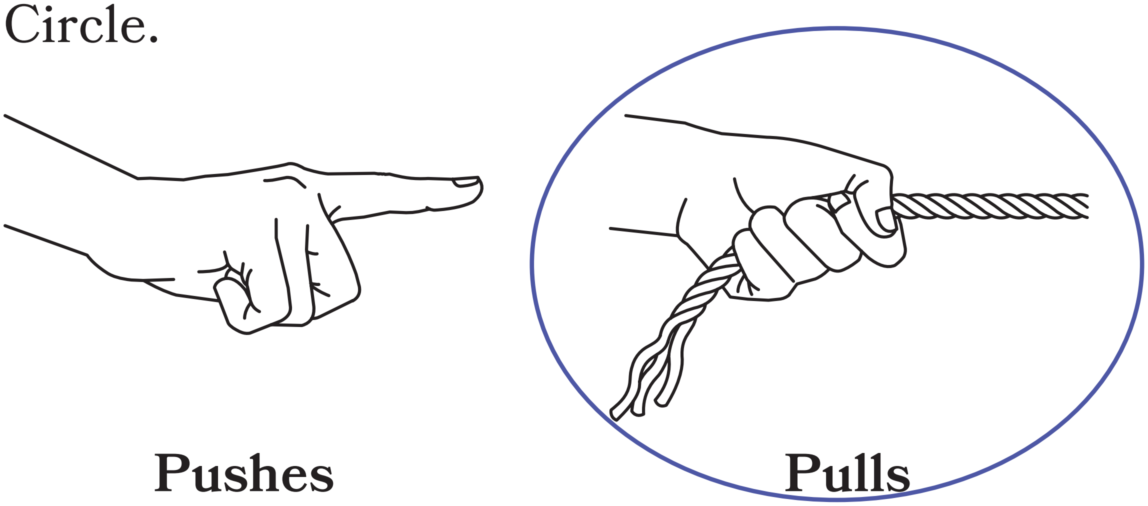
LEVEL K MODULE 2

End-of-Module Assessment

1. To cause the boats to move, should the children use pushes or pulls?



Circle.



2. Look at the data below.

Race 1 Winner	Race 2 Winner	Race 3 Winner
Child B	Child B	Child B

Which child used stronger pulls?

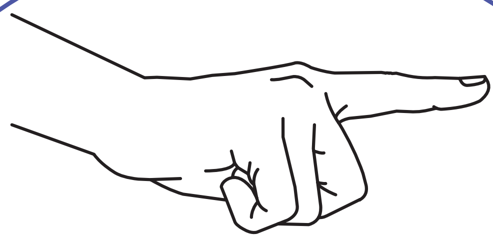
Circle.

Child A **Child B**

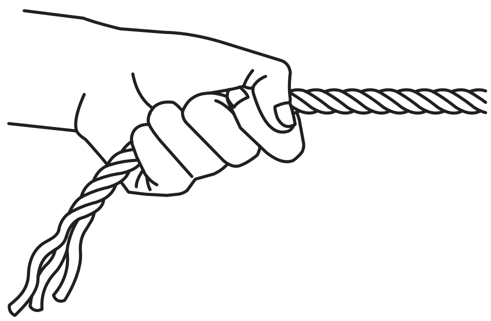
3. Watch the video.

a. Did the wall push or pull on the ball to stop it?

Circle.



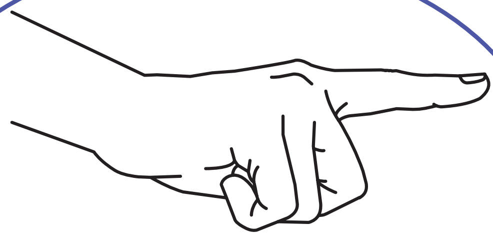
Push



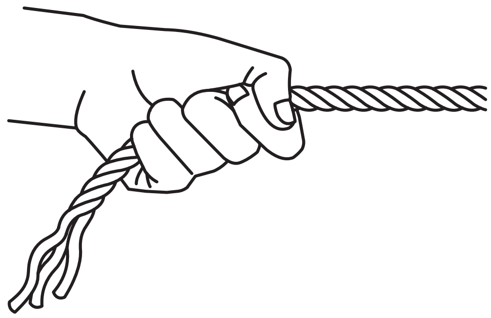
Pull

b. Did the ball push or pull on the wall?

Circle.



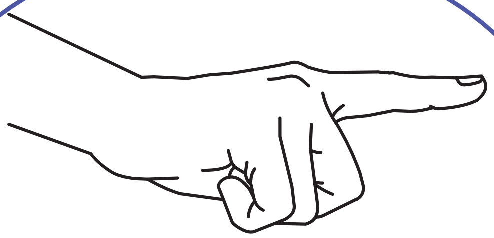
Push



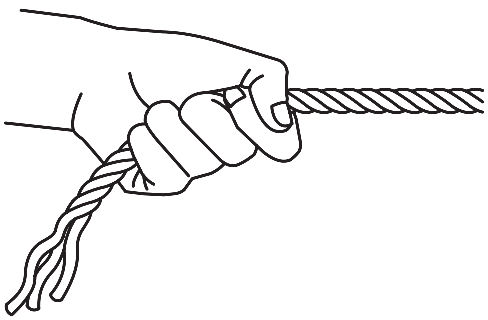
Pull

4. Watch the video. What caused the ball to change direction?

Circle.



A push



A pull

LEVEL K MODULE 2

End-of-Module Assessment Rubric

Score each student's End-of-Module Assessment. The rubric describes evidence of student work that meets expectations. Use the blank spaces as needed to record evidence of student work that exceeds or falls below expectations.

Name: ______________________________ Date: ______________

Item and Standards Addressed		1 **Does Not Yet Meet Expectations** Incorrect or unreasonable response with no detail or evidence	2 **Approaches Expectations** Incorrect or unreasonable response with some detail or evidence OR Correct or reasonable response with insufficient detail or evidence	3 **Meets Expectations** Correct or reasonable response with sufficient detail or evidence	4 **Exceeds Expectations** Correct or reasonable response with more than sufficient detail or evidence	**Score**
1	**K-PS2-1** PS2.A CC.2			The student identifies that pulls will cause the boats to start moving (PS2.A, CC.2).		
2	**K-PS2-1** SEP.3 PS3.C CC.3			The student collects data from the table (SEP.3) and determines that Child B used stronger pulls because Child B's boat was faster (PS3.C, CC.3) in all three races.		
3a	**K-PS2-1** SEP.4 PS2.A PS2.B CC.2			The student watches the video and records the observation (SEP.4) that the wall stopped the ball by pushing on it (PS2.A, PS2.B, CC.2).		

Item and Standards Addressed		1 **Does Not Yet Meet Expectations** Incorrect or unreasonable response with no detail or evidence	2 **Approaches Expectations** Incorrect or unreasonable response with some detail or evidence OR Correct or reasonable response with insufficient detail or evidence	3 **Meets Expectations** Correct or reasonable response with sufficient detail or evidence	4 **Exceeds Expectations** Correct or reasonable response with more than sufficient detail or evidence	Score
3b	**K-PS2-1** SEP.4 PS2.B CC.2			The student watches the video and records the observation (SEP.4) that the ball pushed on the wall (PS2.B, CC.2).		
4	**K-PS2-1** PS2.A CC.2			The student watches the video and selects the option that shows that the wall caused the ball to change direction by pushing on it (PS2.A, CC.2).		

End-of-Module Assessment Alignment Map

For teacher reference, this alignment map lists the NGSS elements assessed by each item in the End-of-Module Assessment.

Item	Performance Expectation*	SEP Element	DCI Element	CC Element
1	K-PS2-1		PS2.A: Forces and Motion ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns.
2	K-PS2-1	SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.	PS3.C: Relationship Between Energy and Forces ▪ A bigger push or pull makes things speed up or slow down more quickly.	CC.3: Scale, Proportion, and Quantity ▪ Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).
3a	K-PS2-1	SEP.4: Analyzing and Interpreting Data ▪ Record information (observations, thoughts, and ideas).	PS2.A: Forces and Motion ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns.
3b	K-PS2-1	SEP.4: Analyzing and Interpreting Data ▪ Record information (observations, thoughts, and ideas).	PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns.
4	K-PS2-1		PS2.A: Forces and Motion ▪ Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	CC.2: Cause and Effect ▪ Events have causes that generate observable patterns.

* The listed Performance Expectations identify items through which students should demonstrate mastery of the relevant Disciplinary Core Idea(s). Students integrate Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas throughout the End-of-Module Assessment. In agreement with the guidance of the NGSS, students may apply Practices and Concepts other than those named in the Performance Expectations.

Appendix A

Module Resources

Contents

Lesson 7 Resource: Stronger and Weaker Push and Pull Cutouts

Lesson 9 Resource A: Skateboard Race Photograph

Lesson 9 Resource B: Skateboard Race Diagram

Lesson 9 Resource C: Conceptual Checkpoint

Lesson 10 Resource A: Two Tugboats Photograph

Lesson 10 Resource B: Small Tugboat Cutouts, Small Push Cutouts, and Small Pull Cutouts

Lesson 14 Resource: Stop Sign Cutout

Lesson 16 Resource: Conceptual Checkpoint

Lesson 17 Resource A: Engineering Challenge Rubric

Lesson 17 Resource B: Tugboat in New York Harbor Photograph

Lesson 17 Resource C: Engineering Design Process Visual

Lesson 17 Resource D: Tugboat at a Dock Photograph

Lesson 17 Resource E: Measurement Paper

Lesson 17 Resource F: Engineering Challenge Setup Instructions and Classroom Procedure

Lesson 17 Resource G: Tugboat Cutouts for Engineering Challenge

Lesson 18 Resource: Results Chart Header Illustrations

Lesson 19 Resource: Lined Measurement Paper

Lesson 20 Resource: Dock Cushion Photographs

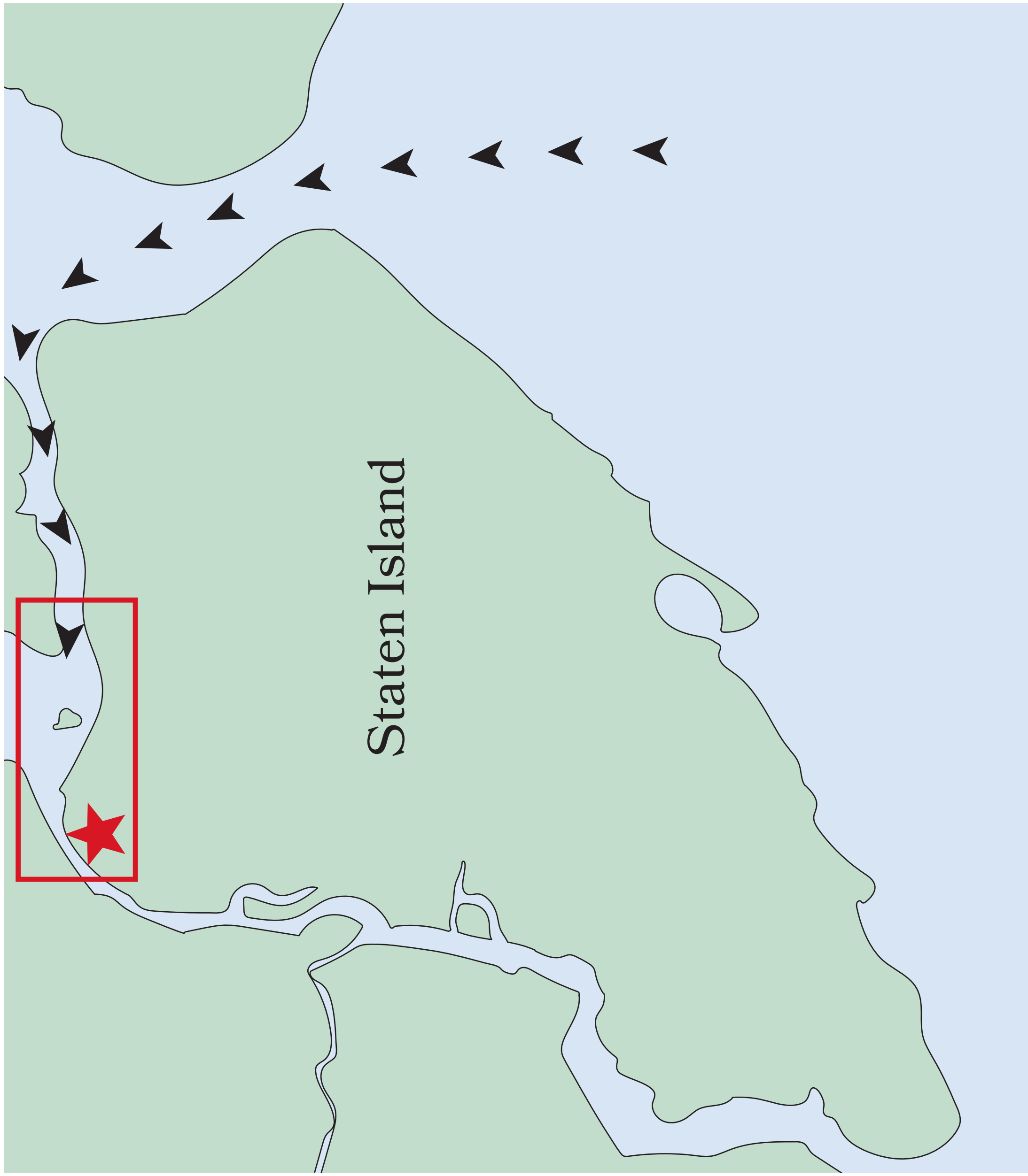
Lesson 21 Resource: Key Term Cards

Lesson 22 Resource: Carnival Game Photographs

Lesson 23 Resource: Crosscutting Concept Cards

LESSON 2 RESOURCE A

Staten Island and New York Harbor Map

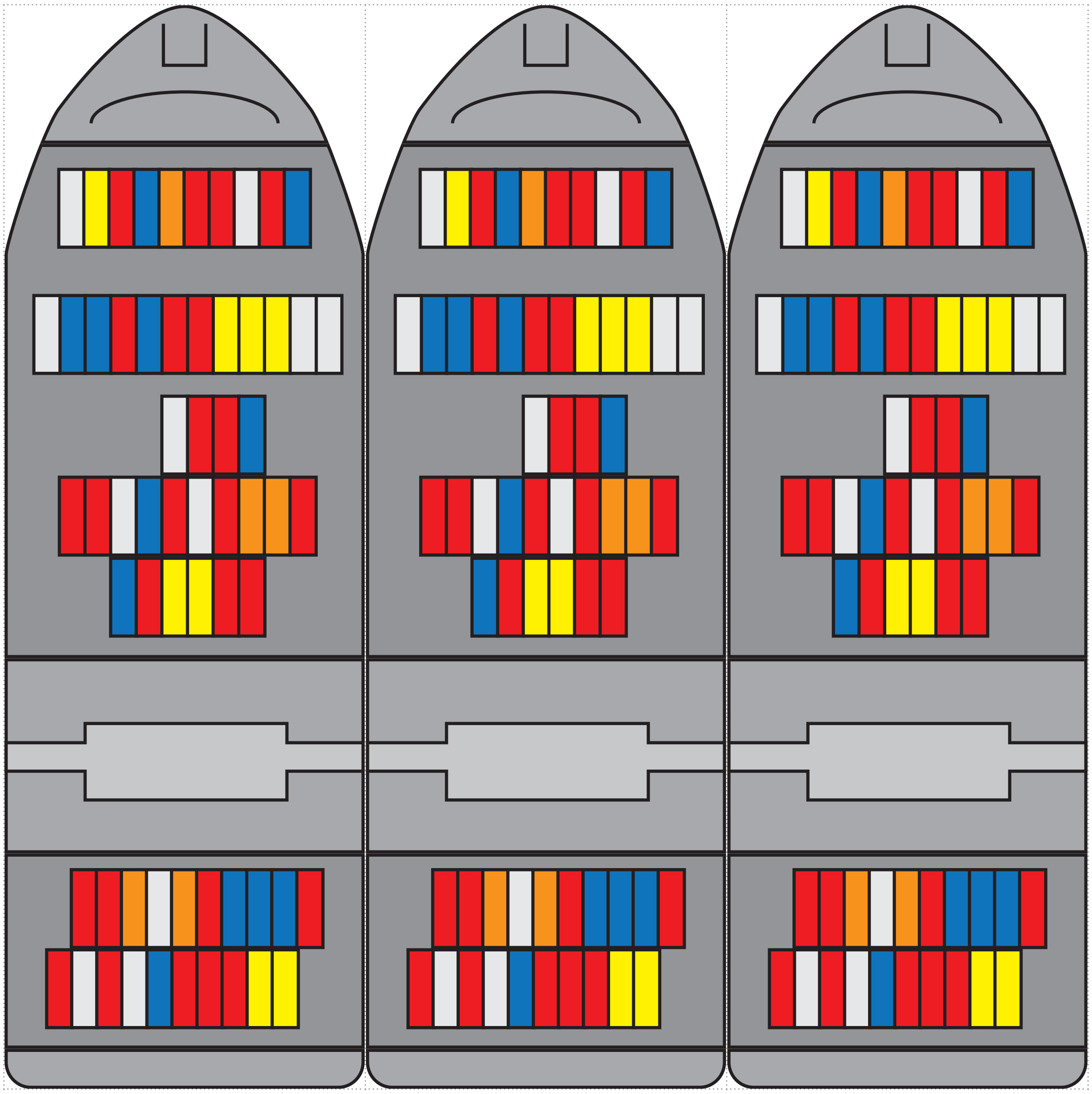


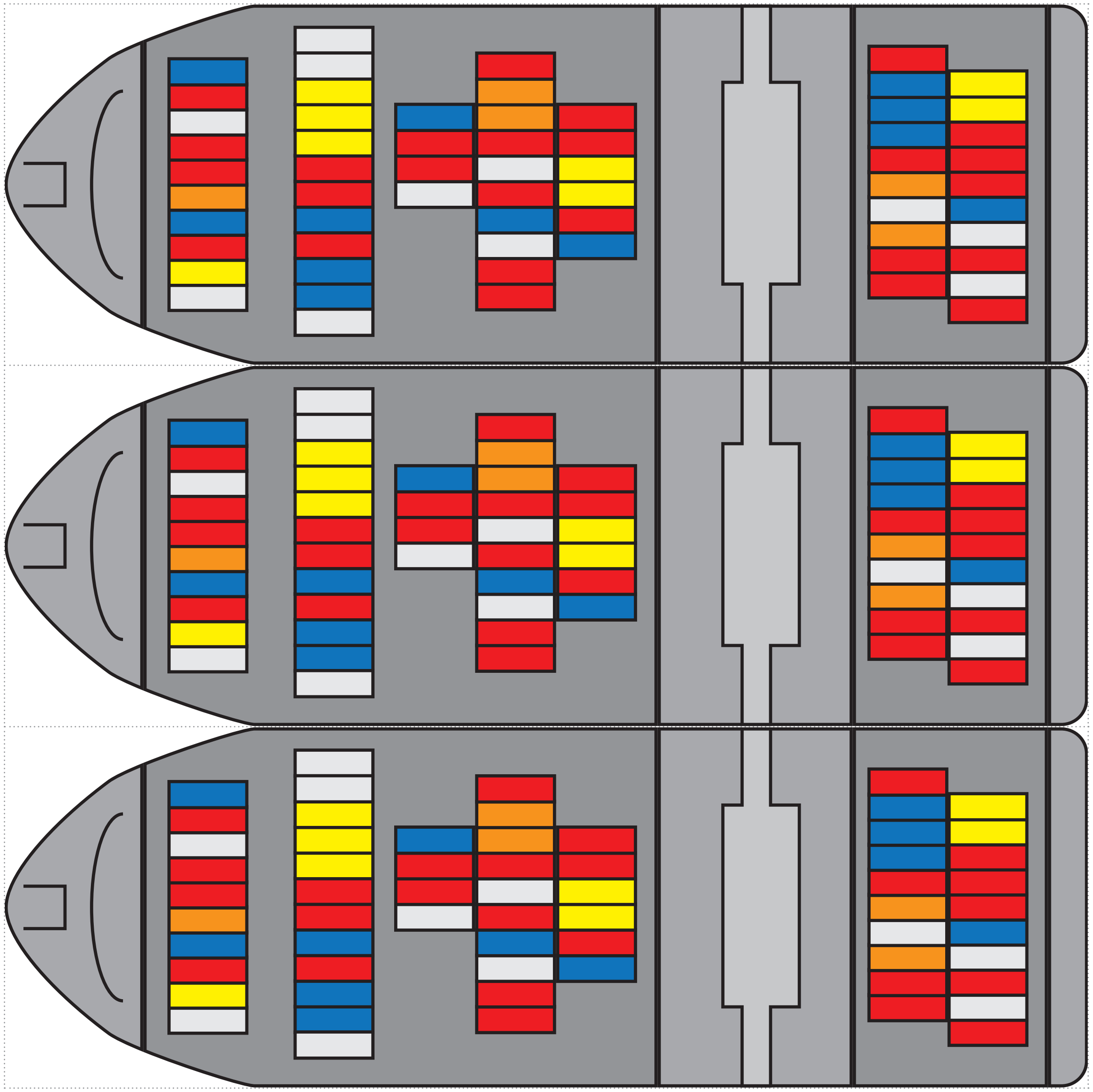
LESSON 2 RESOURCE B

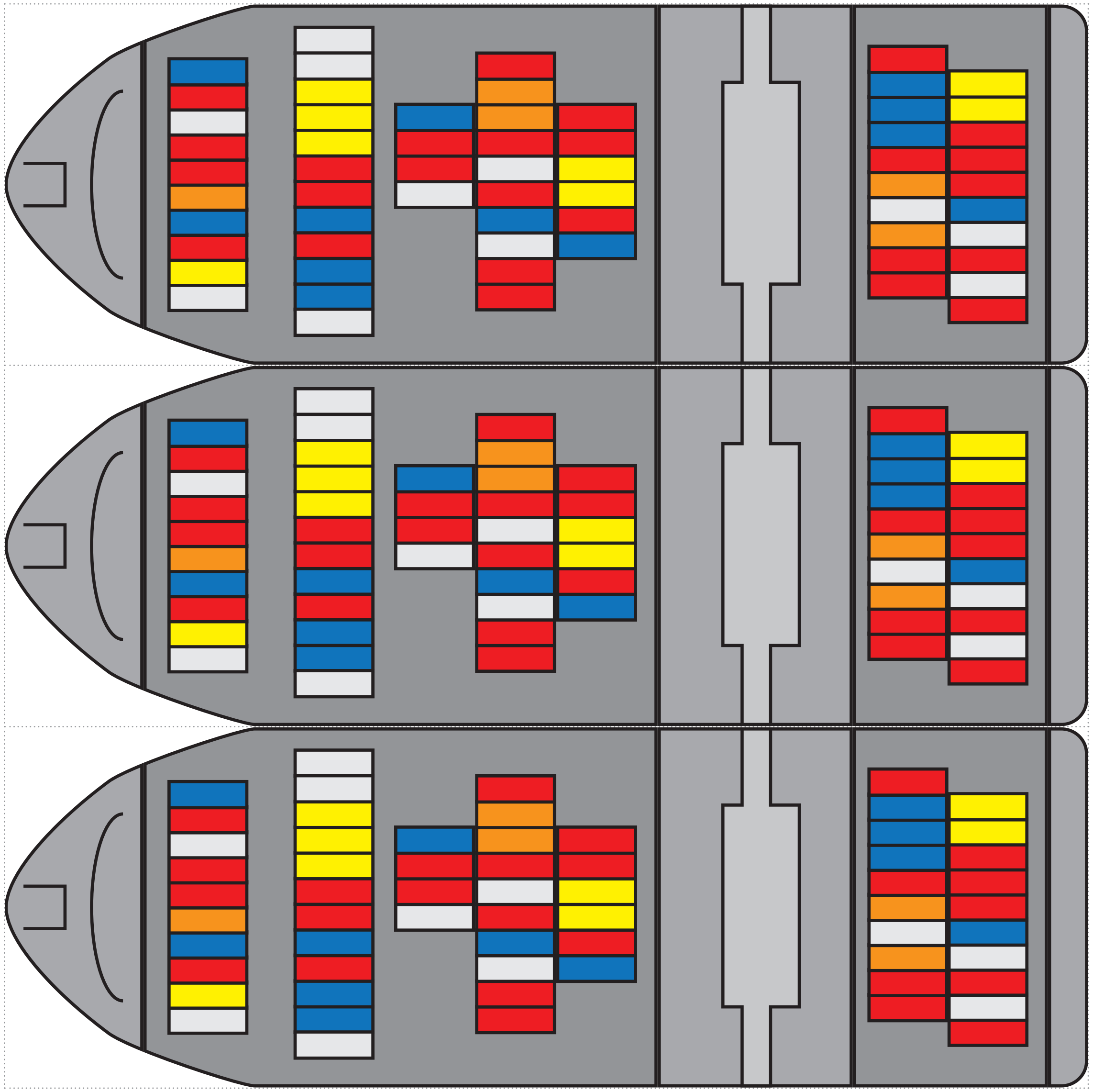
Cargo Ship Cutouts and Tugboat Cutouts

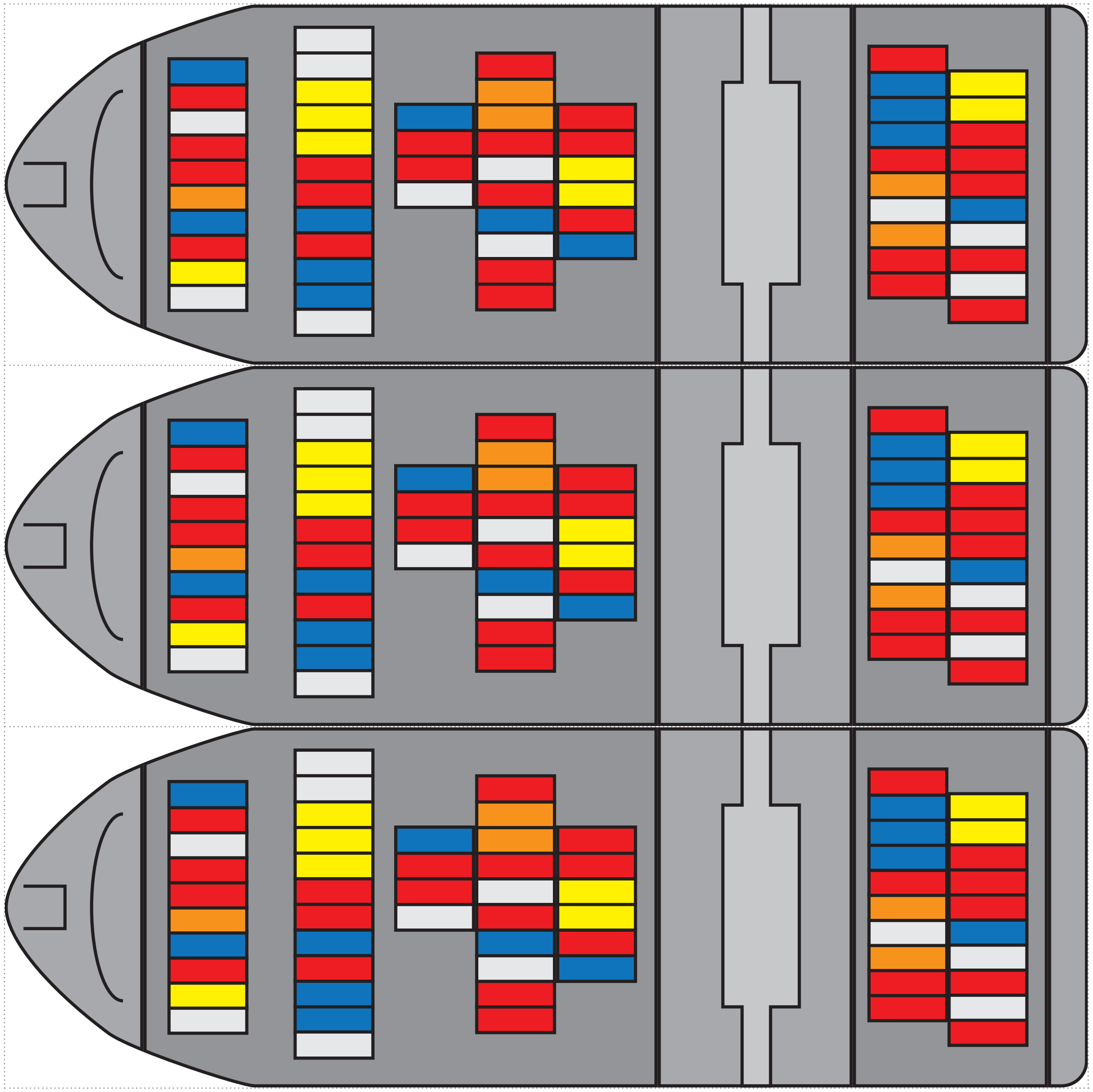
Print one color copy of this resource, and cut out the cargo ship images and tugboat images for use throughout the module. Use these cutouts to develop the anchor model and to set up map models for students. (See Lesson 2 Resource C.)

Cargo Ship Cutouts for Map Models

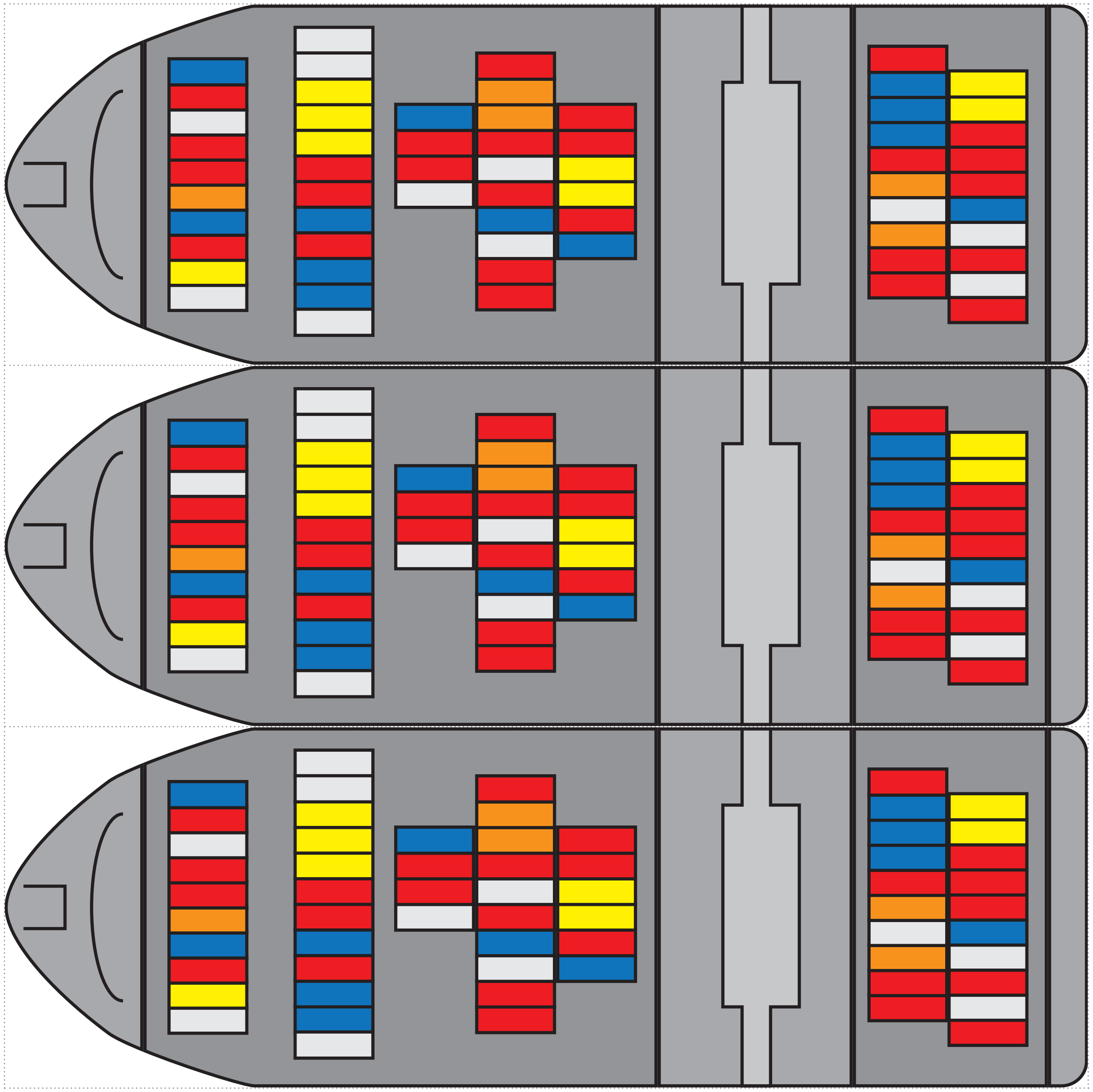




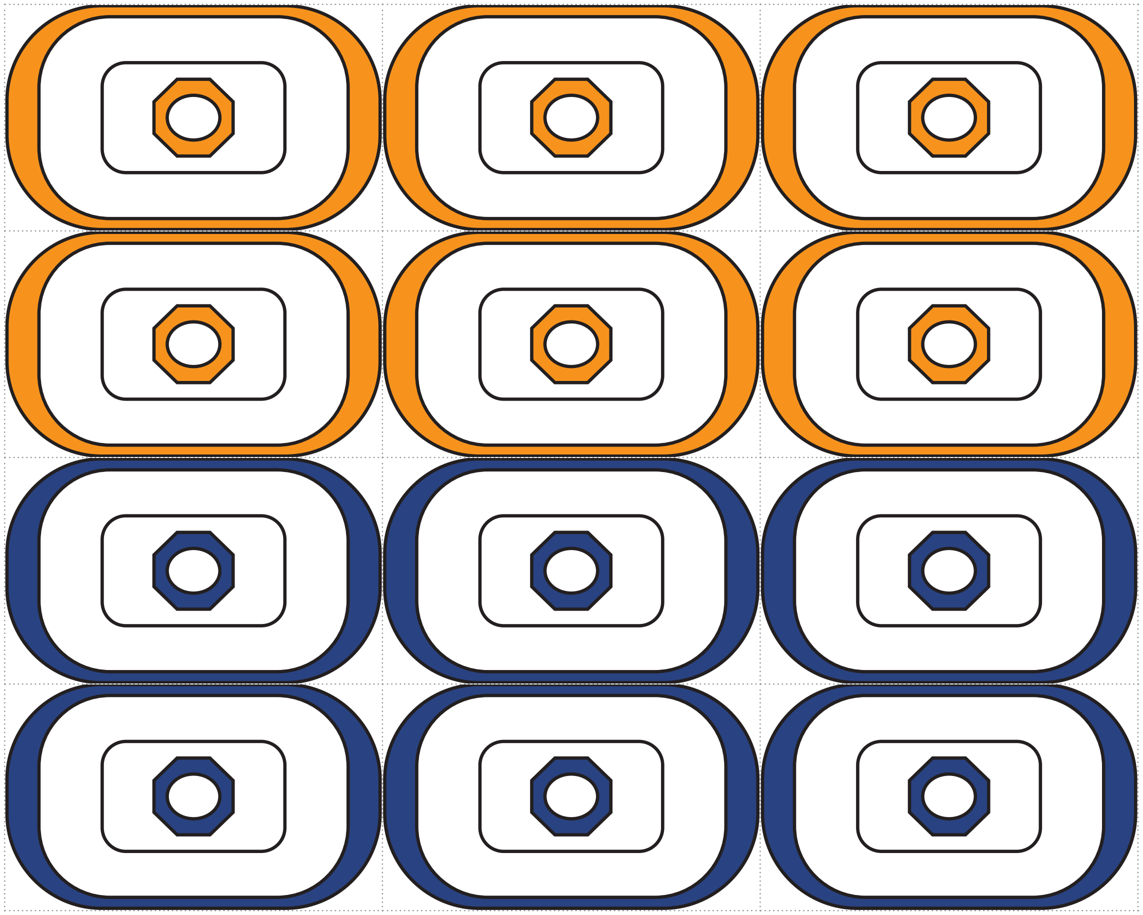




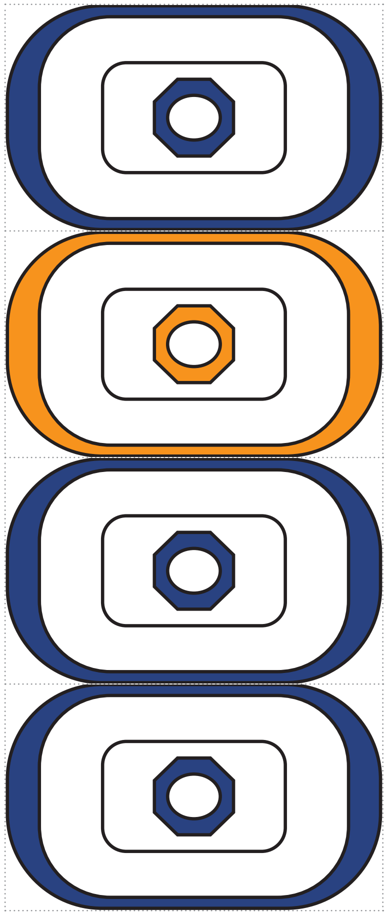
Cargo Ship Cutouts for Anchor Model



Tugboat Cutouts for Map Models



Tugboat Cutouts for Anchor Model



LESSON 2 RESOURCE C

Map Model Setup Instructions

Follow the instructions below to set up wooden block cargo ships and wooden block tugboats for each group's map model before the lesson.

Materials: $\frac{3}{4}$″ vinyl-coated screw-in hooks (4 per group), 3 cm × 5 cm × 1.5 cm wooden block (1 per group), 5 cm × 15 cm × 2 cm wooden block (1 per group), 12″ chenille stem (cut into 4″ pieces, 1 piece per group), cargo ship cutout from Lesson 2 Resource B (1 per group), tugboat cutout from Lesson 2 Resource B (1 per group), glue, ruler (1, optional), scissors (1)

Materials Note: In Lesson 11, each group will require two wooden block tugboats instead of only one, as well as two 4″ chenille stem pieces instead of only one. In Lesson 14, each group will require two wooden block tugboats, two 4″ chenille stem pieces, and two wooden block cargo ships instead of only one of each material. Therefore, if using the Module 2 kit, consider preparing four 12″ chenille stems, all 12 of the smaller wooden blocks, and 12 of the 13 larger wooden blocks. Save the remaining larger wooden block to use without a cargo ship cutout when introducing the water model in Lesson 6.

Preparation

1. Glue the cargo ship cutouts and tugboat cutouts (Lesson 2 Resource B) onto the wooden blocks.

2. Twist two hooks into the top of each wooden block, with one hook centered at each end. Turn the hooks on each block so that their open sides face each other.

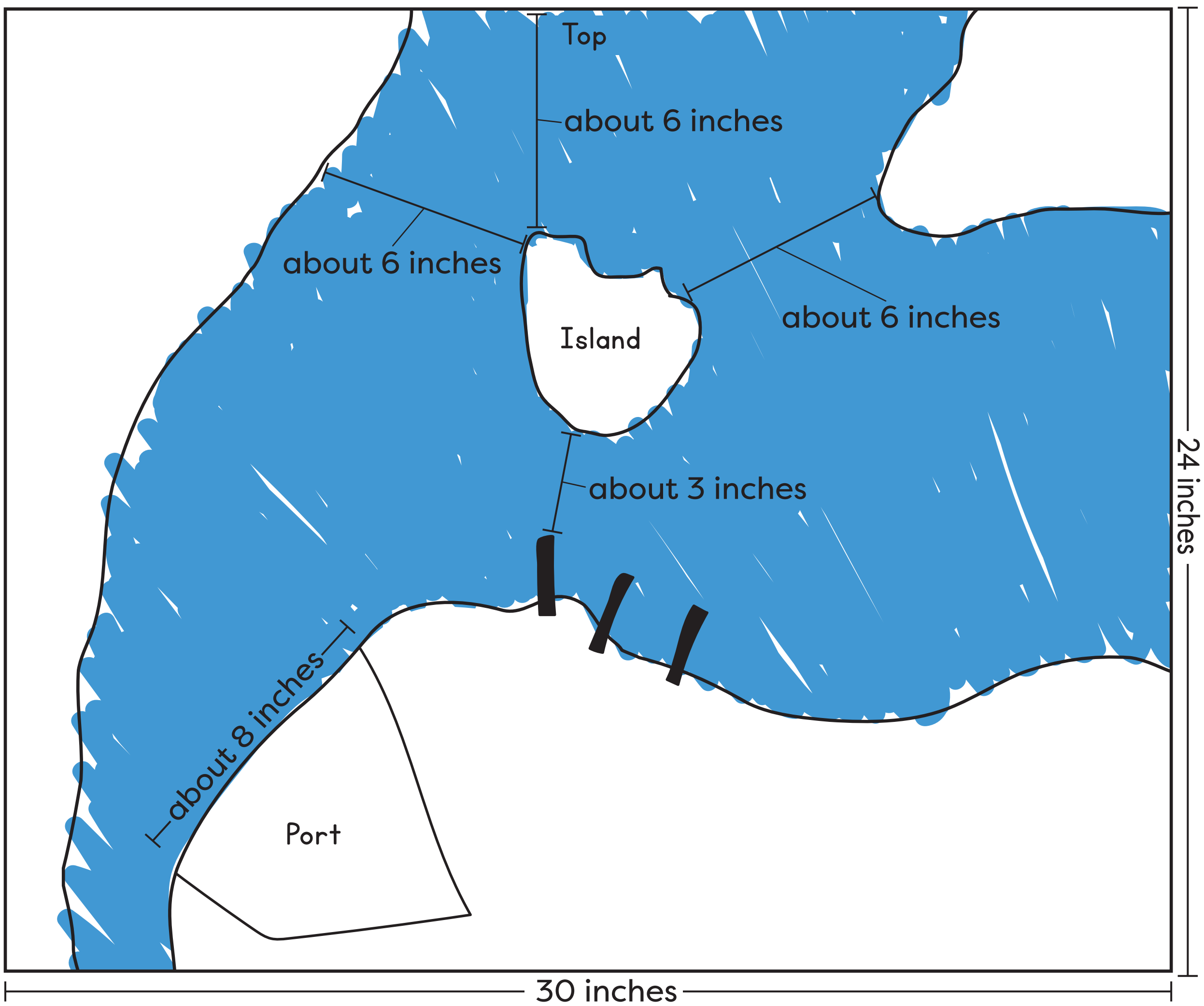
3. Cut each 12″ chenille stem into three 4″ pieces. Create a loop out of each piece by twisting both ends together so that students can easily connect a cargo ship block to a tugboat block by looping a piece around the hooks.

LESSON 2 RESOURCE D

Guide for Creating Harbor Maps

The Module 2 kit includes seven vinyl harbor maps. If the class does not have the kit, use the guide below and draw maps on sheets of chart paper for use throughout the module.

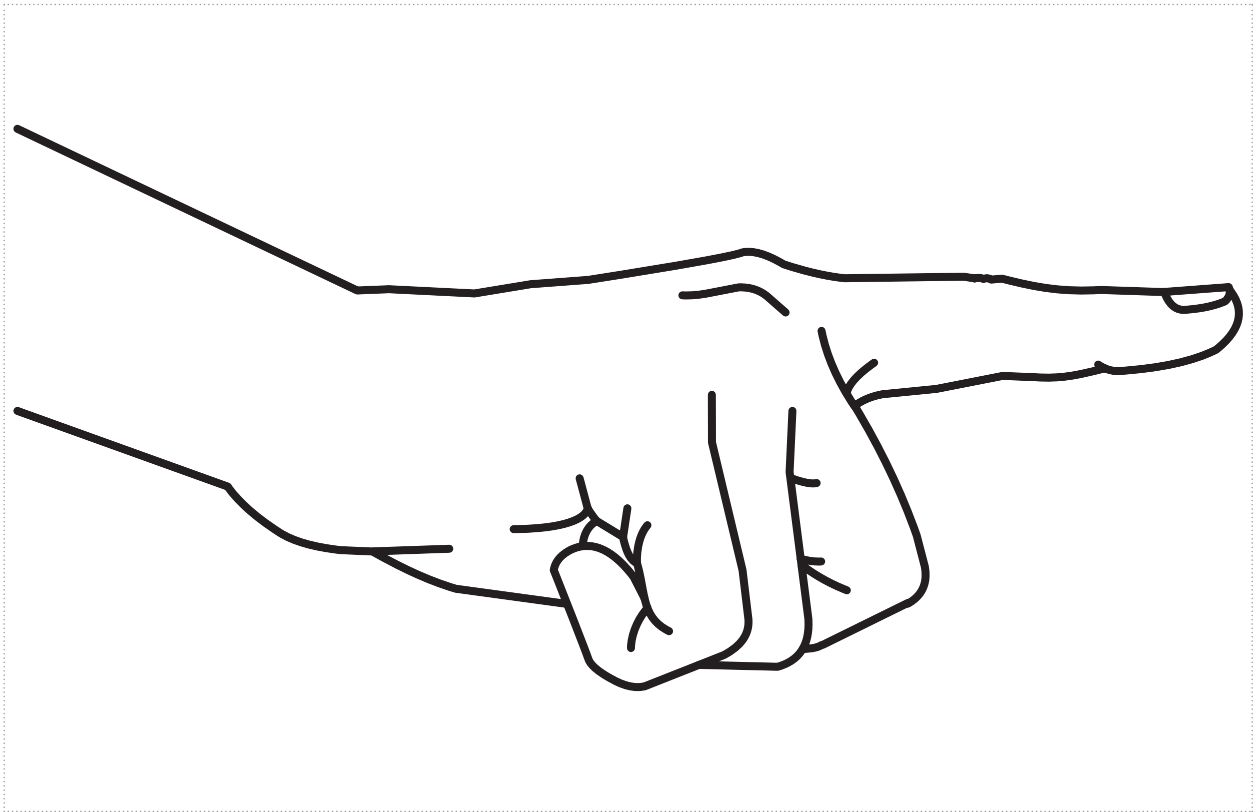
Create one map for the anchor model and at least six additional maps for the map models. Use the measurements on the guide to ensure that the maps can accommodate anchor model updates and student investigations. On each map, color the harbor blue so that students can easily distinguish areas that represent water from those that represent land. Consider adding labels, as shown, to mark the port, the island, and the top of the map. The three black rectangles represent docks.



LESSON 4 RESOURCE A

Push and Pull Chart Header Symbols

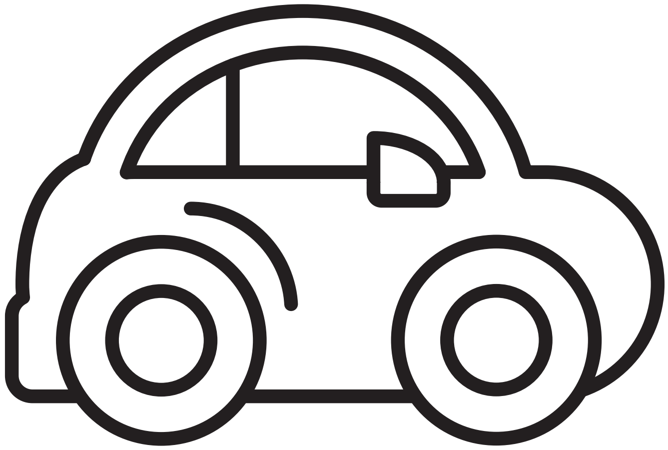
Print and cut out each symbol to place at the top of the push and pull chart. Consider using card stock and laminating for multiple uses.

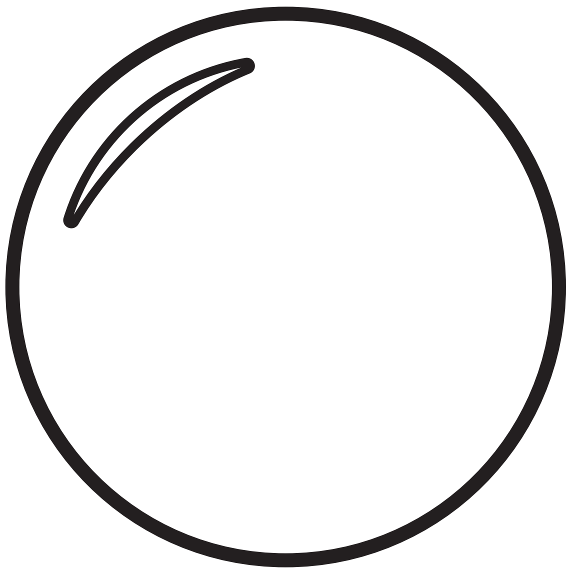


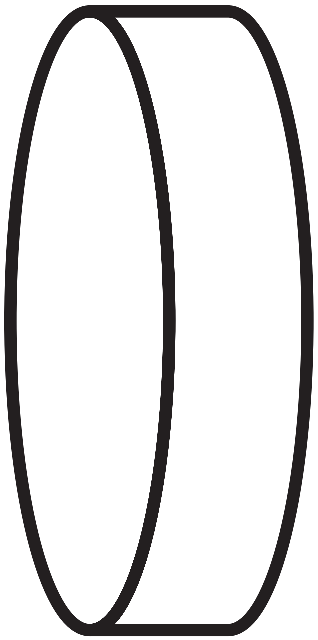
LESSON 4 RESOURCE B

Toy Icon Cards

Print and cut out two sets of cards to use during the sorting activity in Lesson 4. Consider using card stock and laminating for multiple uses. The activity involves placing cards in the Push column and the Pull column of a chart depending on whether groups demonstrate a push or a pull with each toy. Both copies of the sticky hand icon card may end up in the Pull column, but the other three toy icon cards could appear in both columns because groups can push and pull the car, the ball, and the puck.







LESSON 5 RESOURCE A

Toy Stroller Photograph

LESSON 5 RESOURCE B

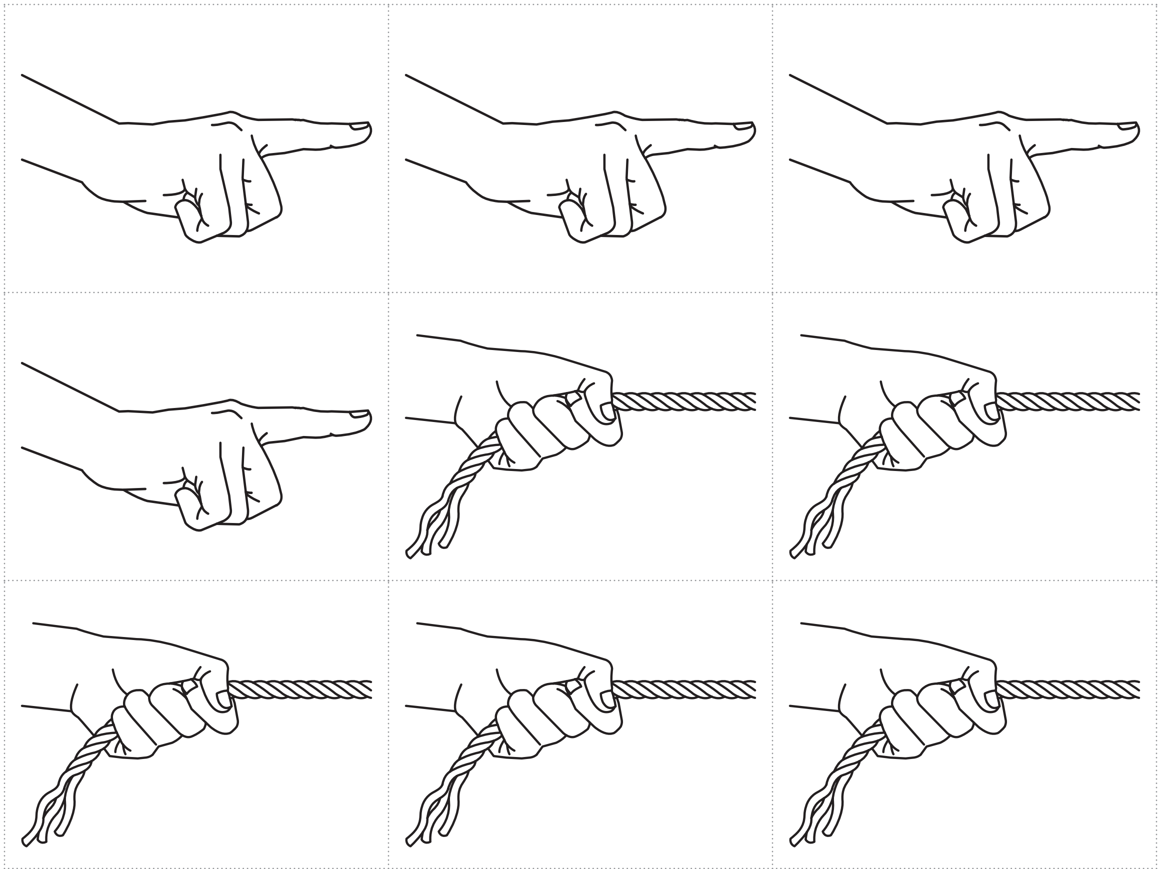
Toy Stroller Icon Card

Print and cut out one copy of this card to add to the push and pull chart that the class developed in the previous lesson. Consider using card stock and laminating for multiple uses.

LESSON 5 RESOURCE C

Push Cutouts and Pull Cutouts

Print and cut out all images for use in Lessons 5 and 6. Consider using card stock and laminating for multiple uses.



LESSON 6 RESOURCE

Water Model Setup Instructions

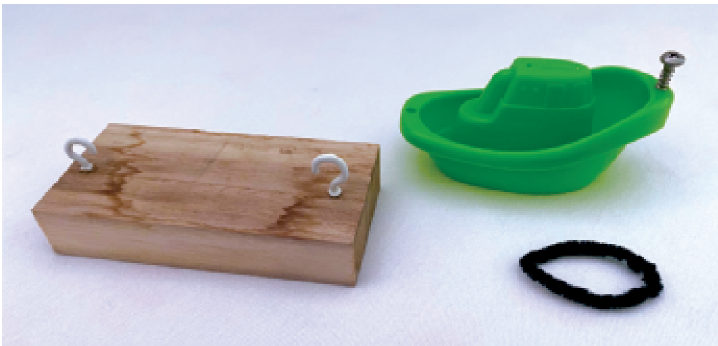
Follow the instructions below to set up the water model, which appears in multiple lessons throughout the module.

Materials: #10 $\frac{3}{4}$″ pan head screw (1), $\frac{3}{4}$″ vinyl-coated screw-in hooks (2), 5 cm × 15 cm × 2 cm wooden block (1), 12″ chenille stem (1), 34″ × 16″ × 6″ or larger plastic bin (1), paper towels, plastic toy tugboat with holes atop front and back ends (1), access to water

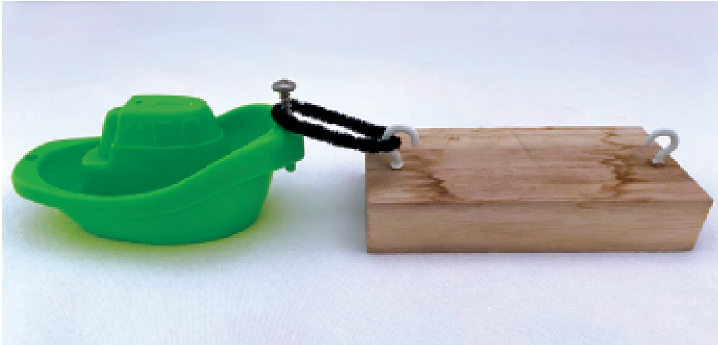
Materials Note: Consider preparing an additional plastic toy tugboat for Lesson 12, which requires use of two tugboats at once. Holes in independently sourced plastic tugboats may require screws of a different diameter and/or length. The screw does not need to have a pan head, but the chenille stem may slip off a flat head screw.

Preparation

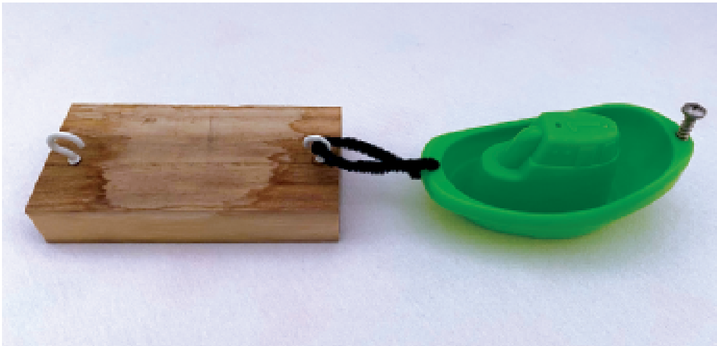
1. Twist the two hooks into the top of the wooden block. Position the hooks so that one hook is centered on each end of the block.
2. Insert the screw into the hole atop the front of the plastic tugboat.
3. Cut the chenille stem into two 6″ pieces, and create a loop out of each piece by twisting both ends together. Save the second piece for use in Lesson 12.



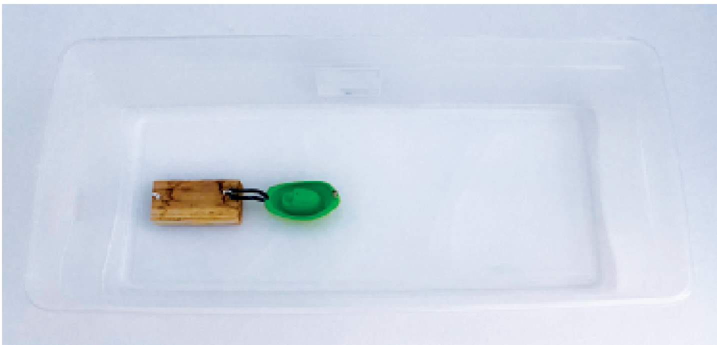
4. To demonstrate a push, connect the plastic tugboat to the wooden block by looping one chenille stem piece around the plastic tugboat's screw and either of the wooden block's hooks. When the plastic tugboat pushes the wooden block, the chenille stem keeps the two objects aligned while they are in the water.



5. To demonstrate a pull, loop a chenille stem piece through the hole in the back of the plastic tugboat and around either of the wooden block's hooks.



6. Fill the bin with 1.5 to 2 inches of water.

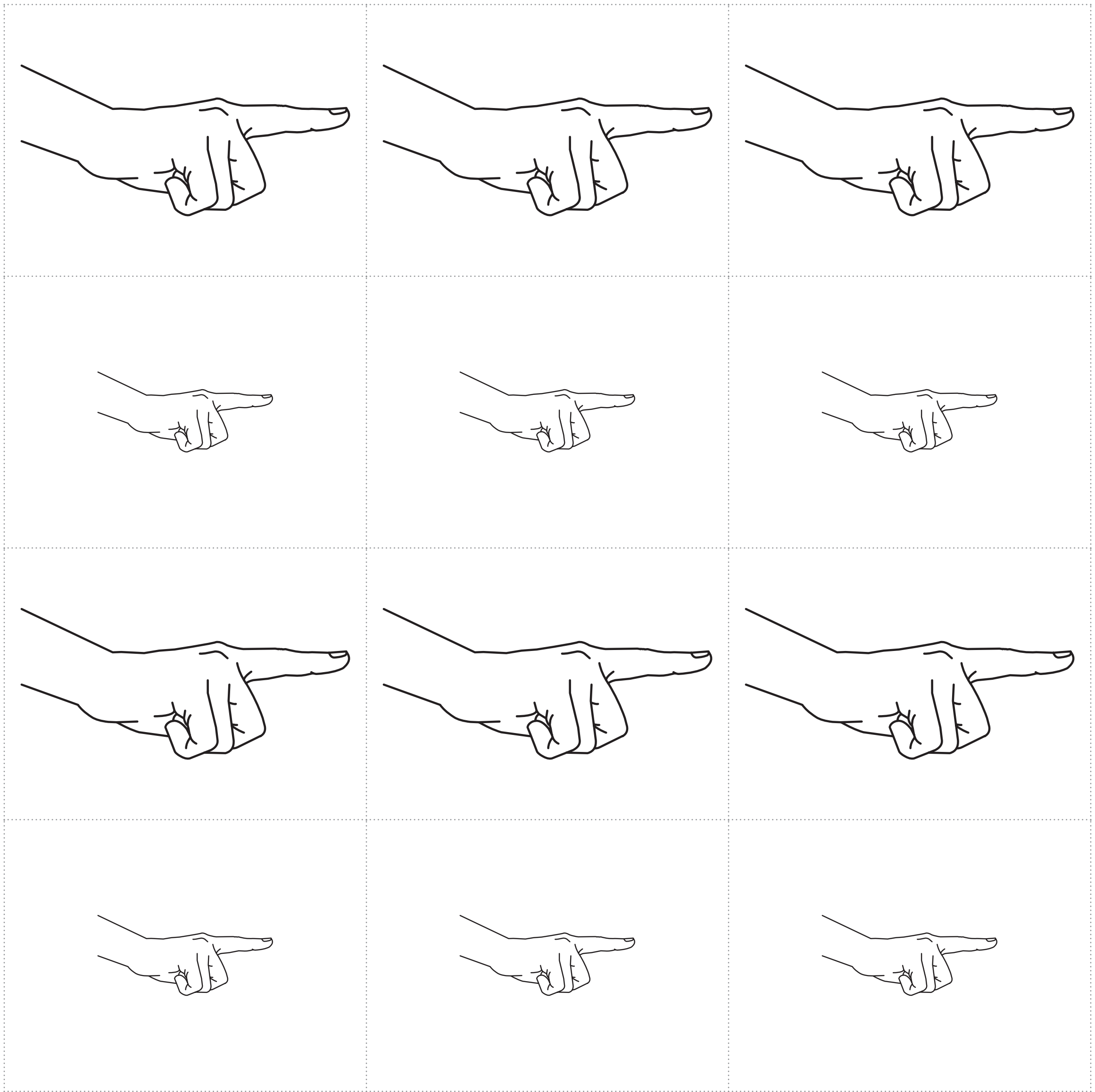


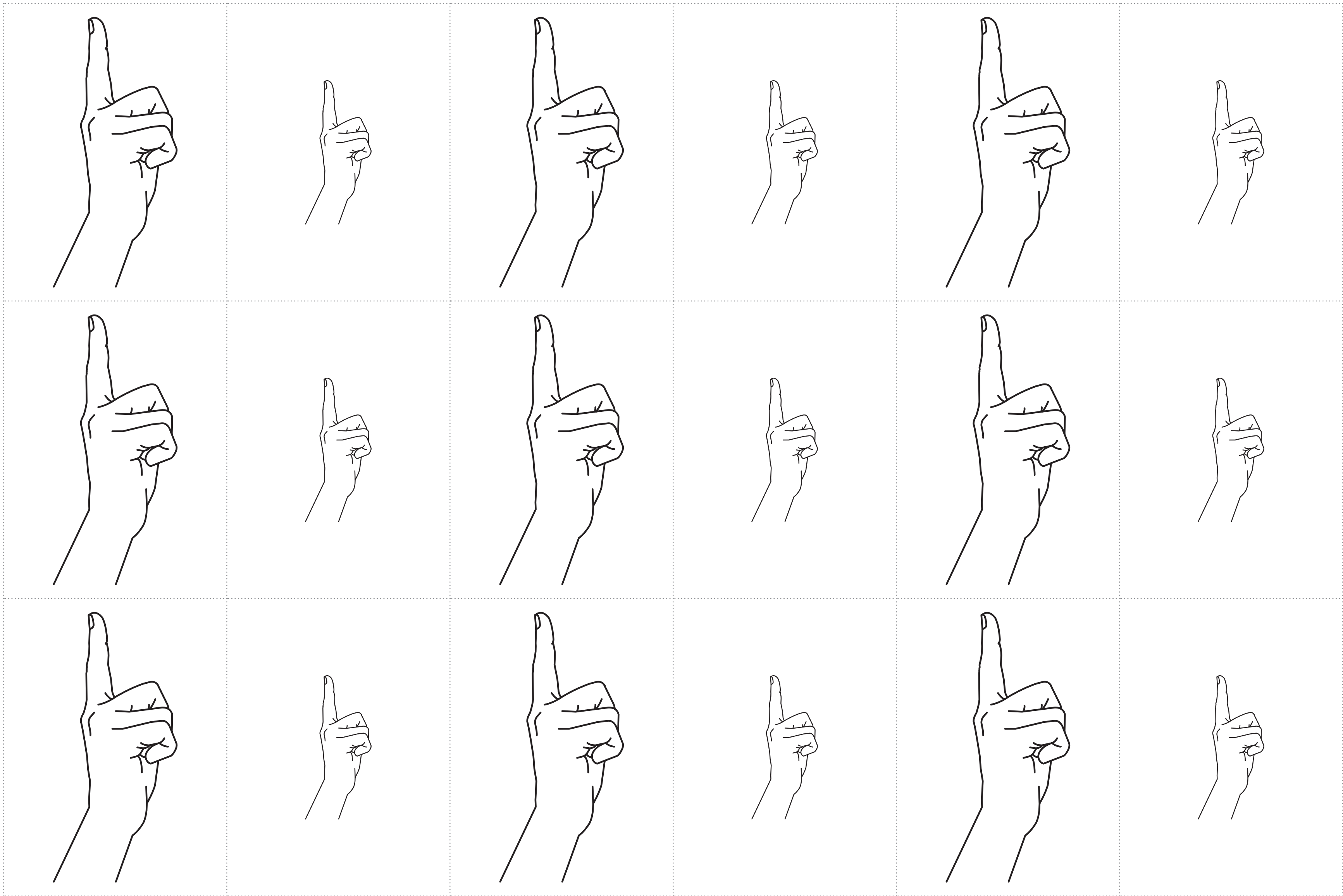
Note: If possible, carry out the demonstration with one group at a time so students can see more easily and participate if time allows. Keep paper towels nearby to wipe up spills immediately. Use care when filling, moving, and emptying the bin. Consider using a cup to scoop some water out of the bin before attempting to empty the bin.

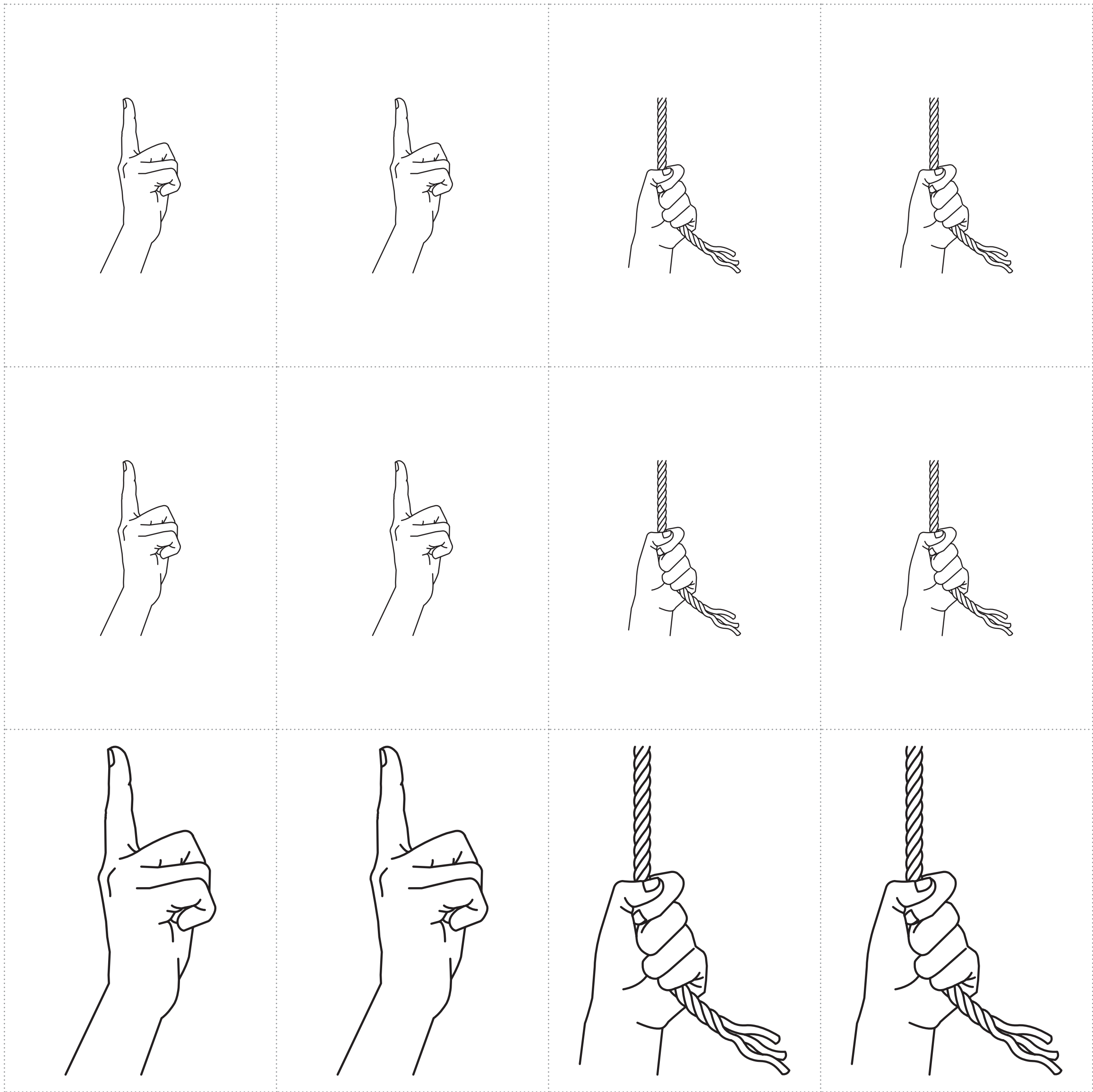
LESSON 7 RESOURCE

Stronger and Weaker Push and Pull Cutouts

Print and cut out enough stronger and weaker push cutouts (the first and second pages of this resource) for every student to receive one of each to glue into their Science Logbooks (Lesson 7 Activity Guide). Also print and cut out the cutouts on the third page of this resource for use when introducing these cutouts to students and when updating the anchor model in Lessons 8, 12, and 14. Consider laminating the cutouts on the third page of this resource for multiple uses. Use the cutouts with larger illustrations to represent stronger pushes and pulls; use the cutouts with smaller illustrations to represent weaker pushes and pulls.





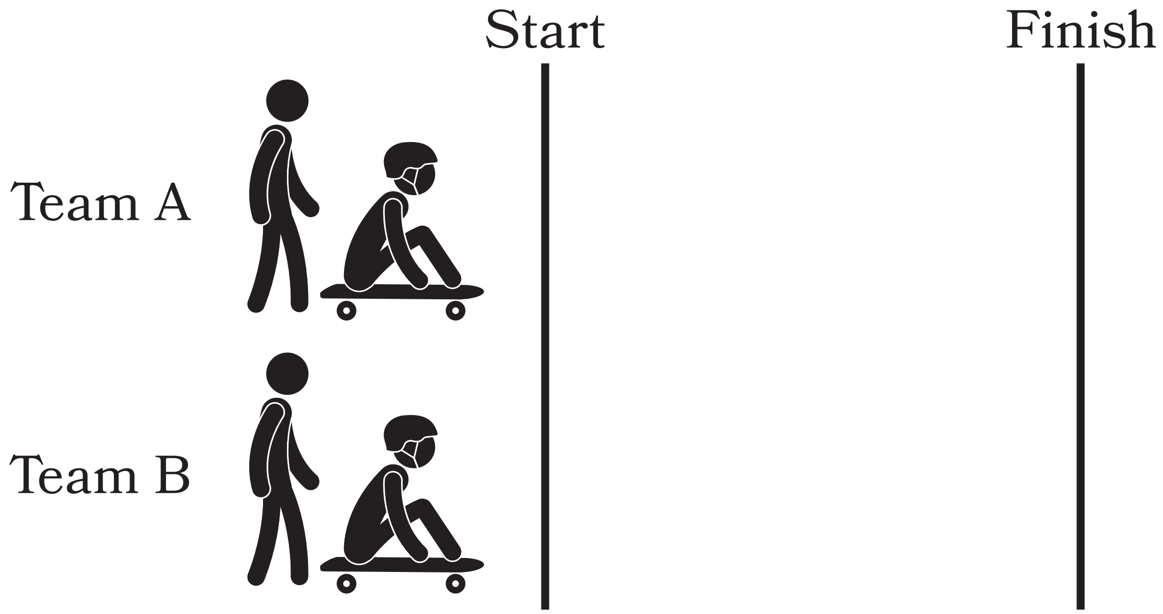


LESSON 9 RESOURCE A

Skateboard Race Photograph

LESSON 9 RESOURCE B

Skateboard Race Diagram



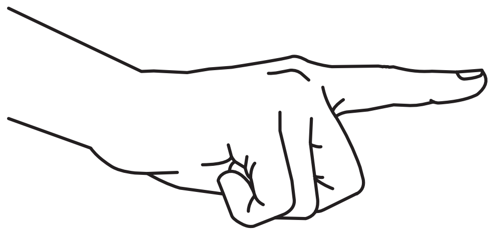
LESSON 9 RESOURCE C

Conceptual Checkpoint

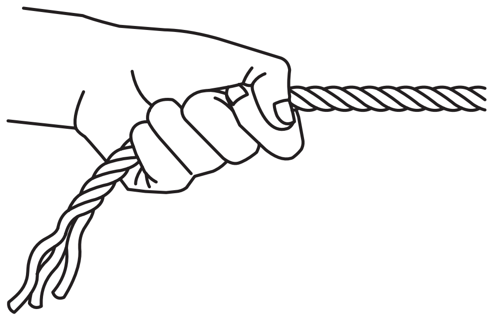
Name: ______________________________

Will a push or a pull cause each rider to move toward the finish line?

Circle.



A push



A pull

Which picture shows the effect of a push?

Circle.

What question about strength can you ask to figure out which team was faster?

Write.

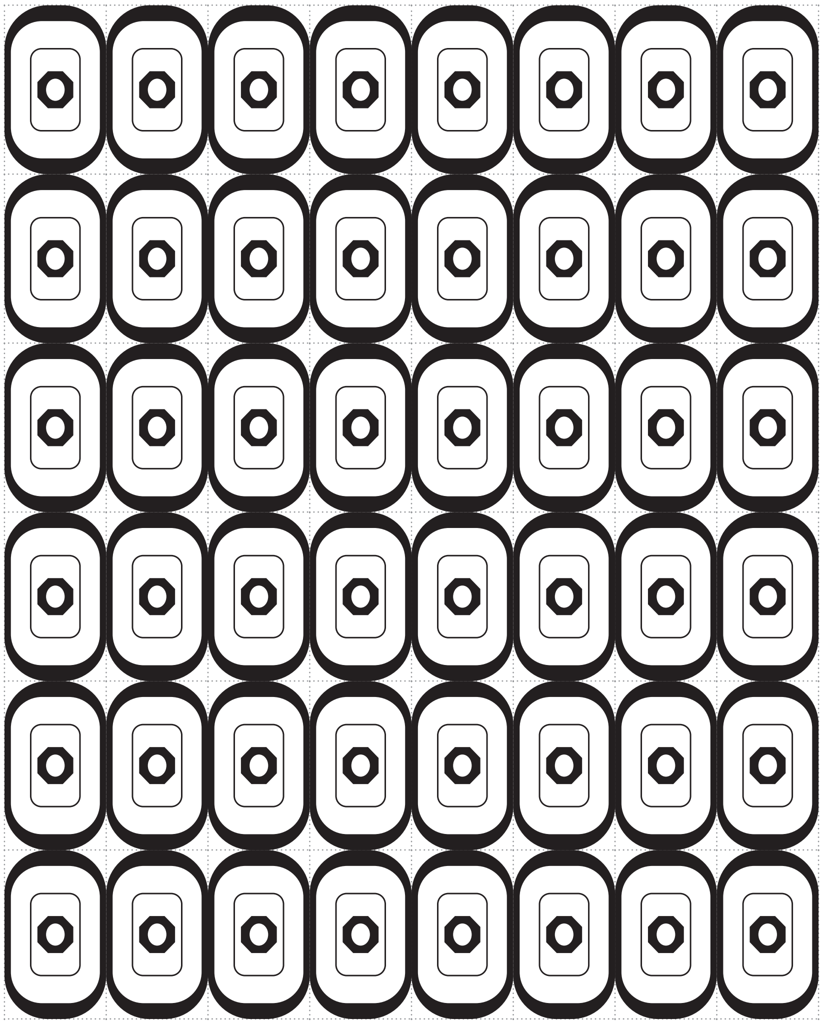
LESSON 10 RESOURCE A

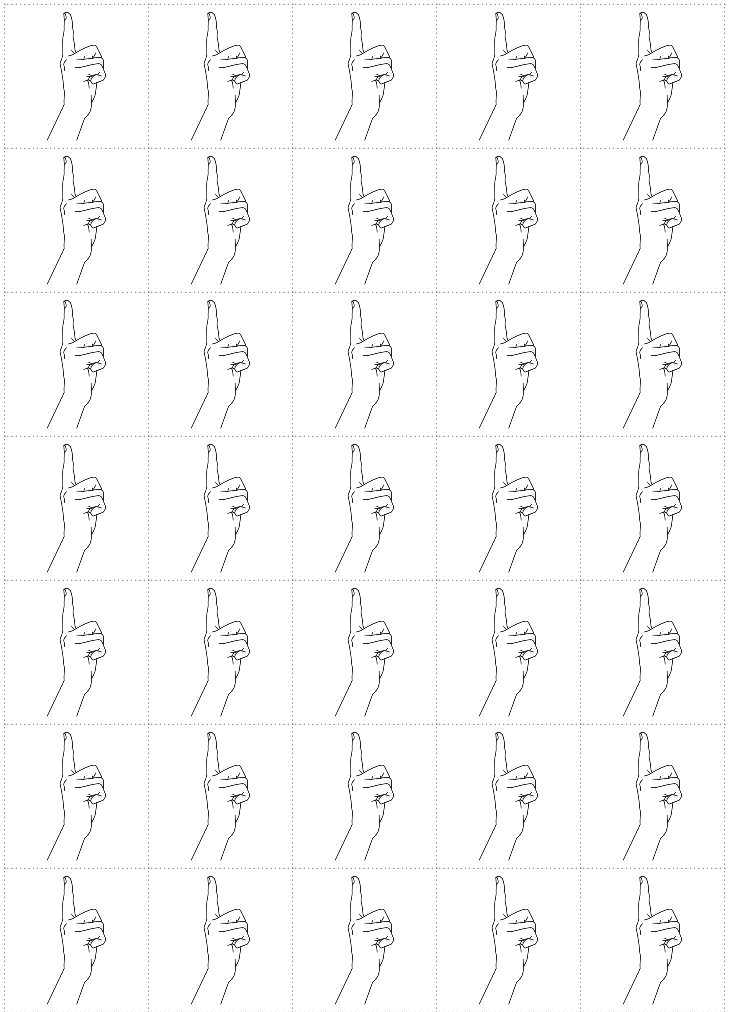
Two Tugboats Photograph

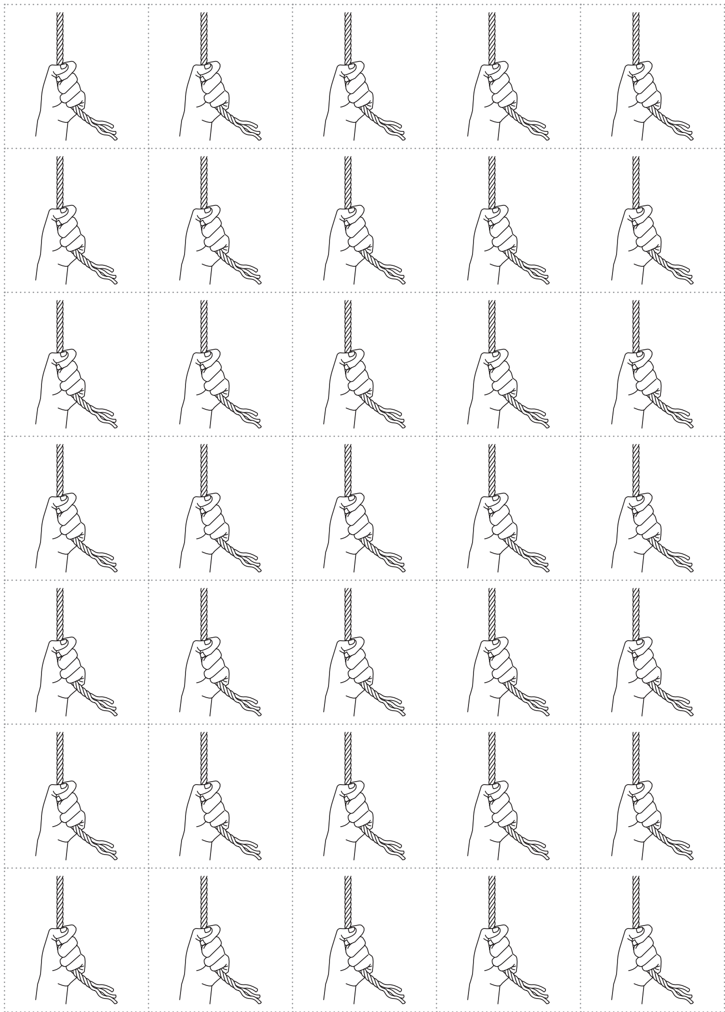
LESSON 10 RESOURCE B

Small Tugboat Cutouts, Small Push Cutouts, and Small Pull Cutouts

Print enough copies of this resource for each student to receive six tugboat cutouts, five push cutouts, and five pull cutouts by the end of the module. For most class sizes, four copies of this resource will be sufficient. Then cut out all the images for use throughout the module. Students will glue these cutouts into their Science Logbooks (Lesson 10 Activity Guide, Lesson 11 Activity Guide, Lesson 13 Activity Guide, and Lesson 18 Activity Guide) and into the Lesson 16 Conceptual Checkpoint.







LESSON 14 RESOURCE

Stop Sign Cutout

Print one color copy of this resource, and cut out the stop sign for use during the final anchor model update.

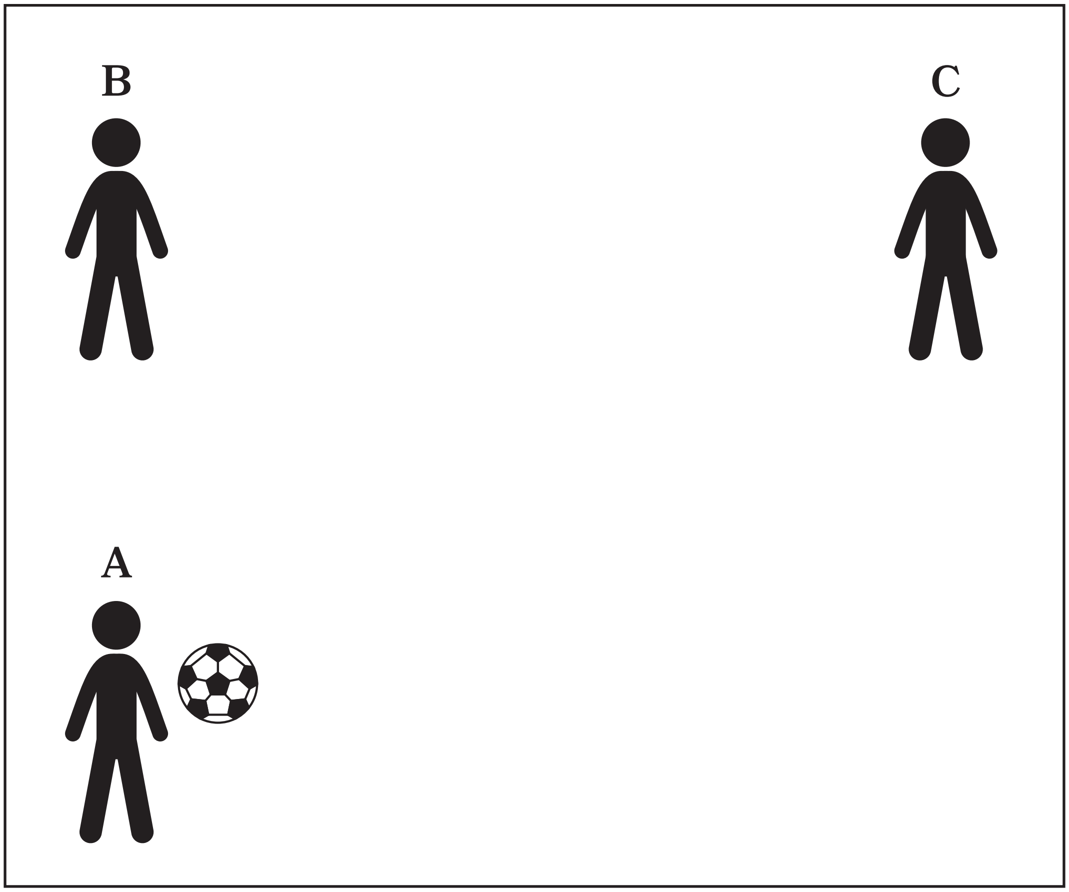
LESSON 16 RESOURCE

Conceptual Checkpoint

Name: ______________________

What is the path of the ball?

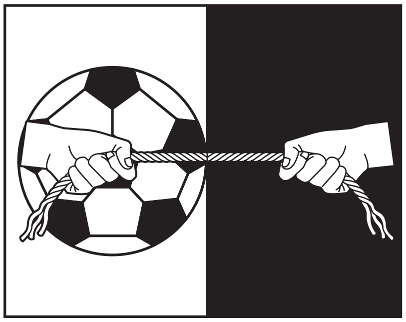
Draw.

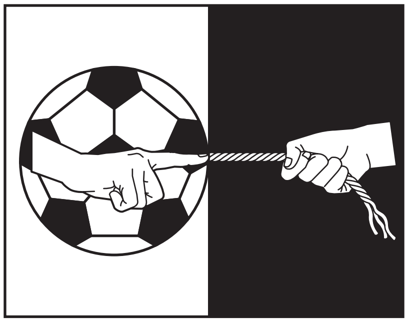


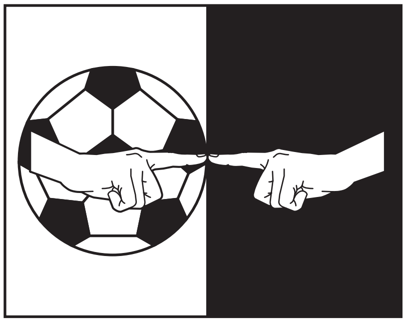
Glue pushes or pulls on the page.

What happens when the ball hits the wall?

Circle.

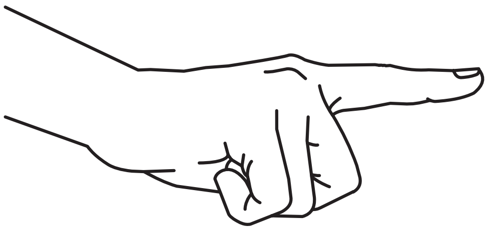




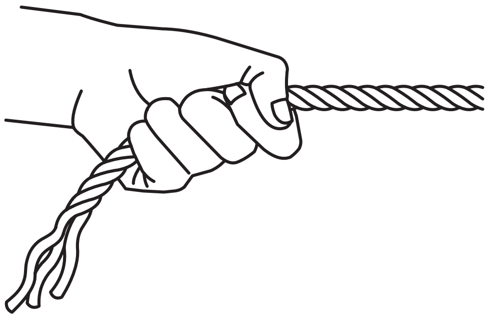


Does the ball push or pull on the wall?

Circle.



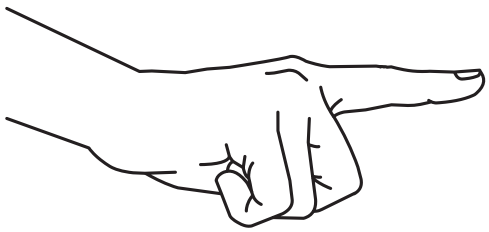
Push



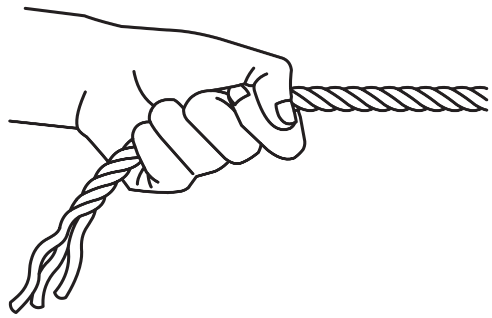
Pull

Does the wall push or pull on the ball?

Circle.



Push



Pull

LESSON 17 RESOURCE A

Engineering Challenge Rubric

Score each student's engagement in the Engineering Challenge. The rubric describes evidence of student engagement that meets expectations for each stage of the engineering design process. Use the blank spaces as needed in the rubric to record evidence of student work that exceeds or falls below expectations.

Name: ______________________________ Date: ______________

Engineering Design Process Stage and Standards Addressed		**1** **Does Not Yet Meet Expectations** No evidence of engagement in stage	**2** **Approaches Expectations** Some evidence of engagement in stage	**3** **Meets Expectations** Sufficient evidence of engagement in stage	**4** **Exceeds Expectations** More than sufficient evidence of engagement in stage	**Score**
Ask	SEP.3 PS2.B CC.1			The student compares how the Hall's car and the wooden tugboat move after they bump into the model dock (SEP.3) and identifies the pattern that when the model tugboats touch the dock, their movement changes (CC.1, PS2.B).		
Imagine	SEP.3 PS2.B CC.2			The student conducts tests to observe and compare different materials (SEP.3) and to determine how each material causes the movement of the model tugboat to change (CC.2, PS2.B).		

Engineering Design Process Stage and Standards Addressed		1 Does Not Yet Meet Expectations No evidence of engagement in stage	2 Approaches Expectations Some evidence of engagement in stage	3 Meets Expectations Sufficient evidence of engagement in stage	4 Exceeds Expectations More than sufficient evidence of engagement in stage	Score
Plan	SEP.6 ETS1.B CC.2			The student selects materials and creates a drawing to communicate an idea (ETS1.B) for a cushion design (SEP.6) that could cause the model tugboat to stop closer to the dock (CC.2).		
Create	SEP.5 PS2.B CC.2			The student uses counting and numbers to collect data from tests (SEP.5) to determine whether a push from the cushion causes the model tugboat to stop closer to the dock (PS2.B, CC.2).		
Improve	SEP.3 PS2.B CC.2			The student observes and compares cushions made of different materials and uses these comparisons to improve a cushion design (SEP.3) so it is more effective at helping the model tugboat stop closer to the dock (CC.2) after the tugboat touches the cushion (PS2.B).		

Engineering Design Process Stage and Standards Addressed		1 **Does Not Yet Meet Expectations** No evidence of engagement in stage	2 **Approaches Expectations** Some evidence of engagement in stage	3 **Meets Expectations** Sufficient evidence of engagement in stage	4 **Exceeds Expectations** More than sufficient evidence of engagement in stage	Score
Share	SEP.5 PS2.B ETS1.A CC.1			The student determines which solutions best address the problem (ETS1.A) by comparing measurements of the model tugboat's bounces (SEP.5) and noticing patterns (CC.1) in how different materials change the tugboat's movement (PS2.B).		

Engineering Challenge Alignment Map

For teacher reference, this alignment map lists the NGSS elements assessed in each stage of the engineering design process during the Engineering Challenge.

Stage	SEP Element	DCI Element	CC Element
Ask	SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.	PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.1: Patterns ▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.
Imagine	SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.	PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.
Plan	SEP.6: Constructing Explanations and Designing Solutions ▪ Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem.	ETS1.B: Developing Possible Solutions ▪ Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.	CC.2: Cause and Effect ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.
Create	SEP.5: Using Mathematics and Computational Thinking ▪ Use counting and numbers to identify and describe patterns in the natural and designed world(s).	PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.
Improve	SEP.3: Planning and Carrying Out Investigations ▪ Make observations (firsthand or from media) and/or measurements of a proposed object, tool, or solution to determine if it solves a problem or meets a goal.	PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion.	CC.2: Cause and Effect ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.

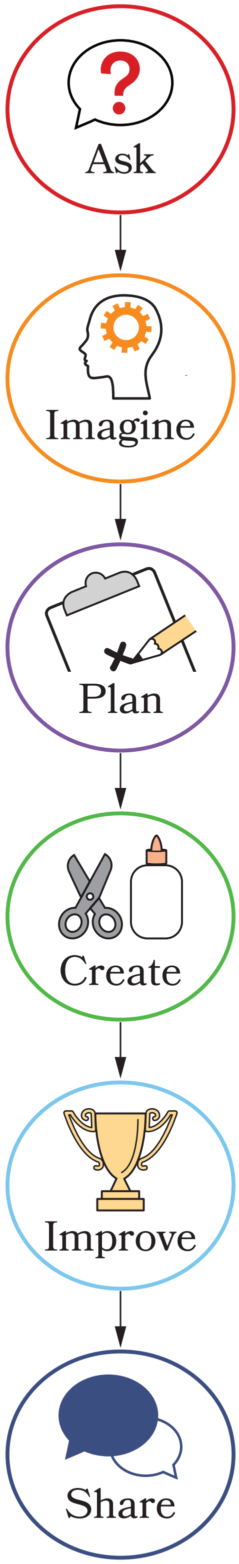
Stage	SEP Element	DCI Element	CC Element
Share	SEP.5: Using Mathematics and Computational Thinking ▪ Use counting and numbers to identify and describe patterns in the natural and designed world(s).	PS2.B: Types of Interactions ▪ When objects touch or collide, they push on one another and can change motion. ETS1.A: Defining Engineering Problems ▪ A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.	CC.1: Patterns ▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

LESSON 17 RESOURCE B

Tugboat in New York Harbor Photograph

LESSON 17 RESOURCE C

Engineering Design Process Visual

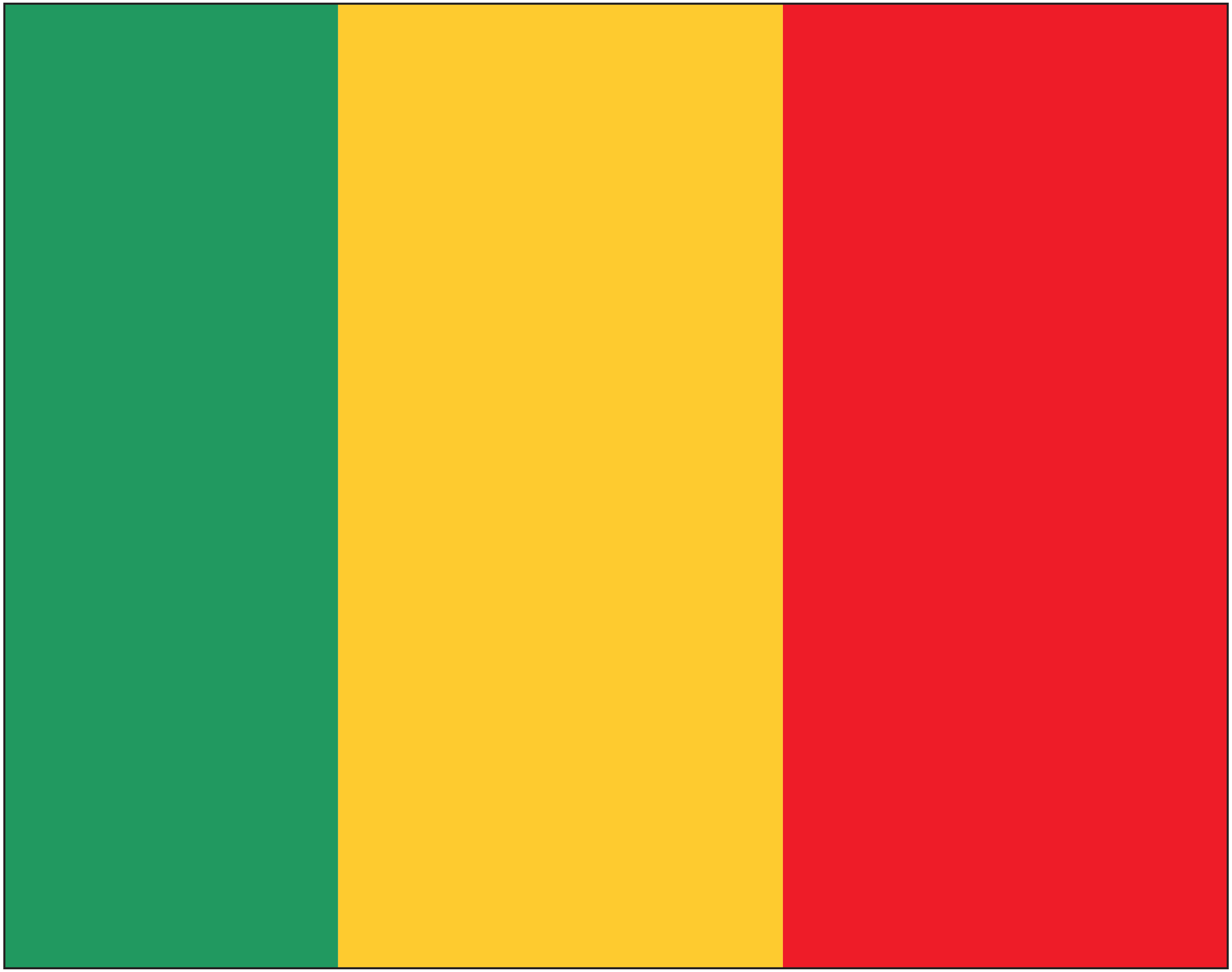


LESSON 17 RESOURCE D

Tugboat at a Dock Photograph

LESSON 17 RESOURCE E

Measurement Paper



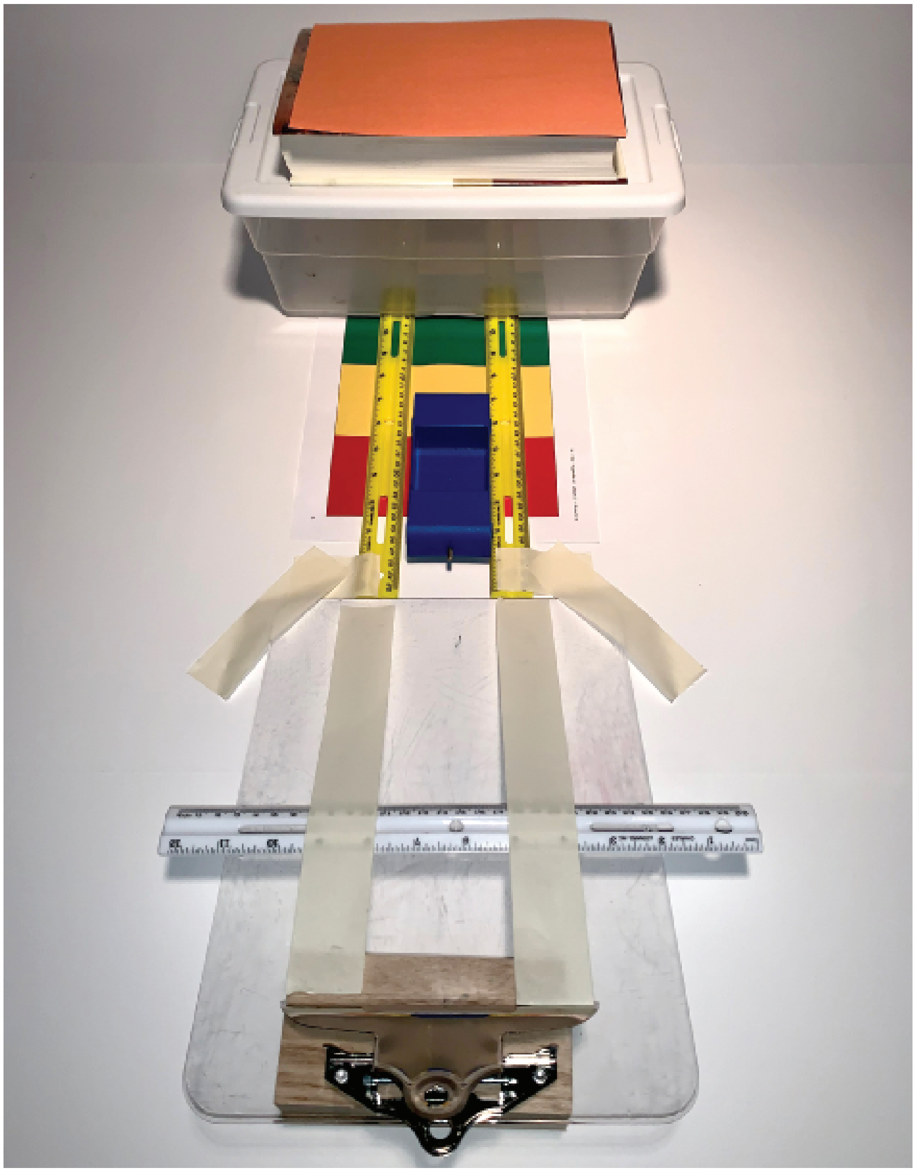
LESSON 17 RESOURCE F

Engineering Challenge Setup Instructions and Classroom Procedure

This resource provides instructions for setting up dock cushion testing stations, as well as for preparing Imagine stage testing bags and Create stage materials. This resource also describes the classroom procedure for demonstrating to students how to use the testing stations.

Setup Instructions

Dock Cushion Testing Stations



Materials (1 set per station): 5 cm × 15 cm × 2 cm wooden blocks (2), 6 qt clear plastic bin with lid (1), books or other objects that can serve as weights (5 lb), smooth clipboard (1), prepared tugboat cutout from Lesson 17 Resource G (1, optional), Hall's car (1), color copy of Lesson 17 Resource E (1 for use in Lessons 17 and 18 only), color copy of Lesson 19 Resource (1 for use in Lesson 19 only), masking tape, plastic rulers (3)

Materials Note: Any 12″ rulers will work, as long as the rulers are flat enough along the edges to permit the Hall's car to move between them without the car's plastic frame touching them. For this reason, plastic rulers may work better than wooden ones. If the Hall's car has a small metal bolt on one end, make sure to orient the car so that this bolt is facing away from the bin when positioning the car on the clipboard.

The weights on top of or inside of each Dock Cushion Testing Station bin must be as similar as possible. If the amount of weight on top of each bin is different or if the 5 lb weight is distributed differently, each bin will push back against the Hall's car with a different amount of force, and the stations will produce different results for the same cushion.

Preparation

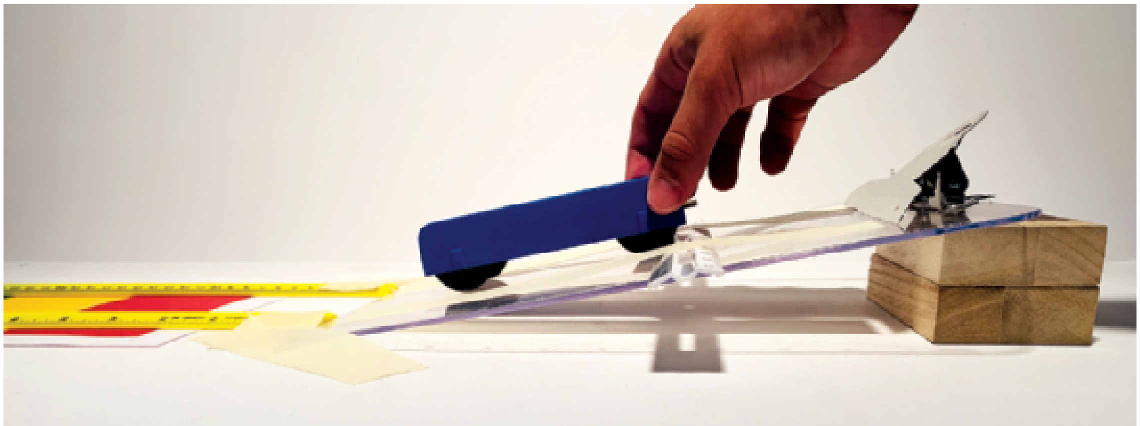
Follow the instructions below before Lesson 17 to set up one Dock Cushion Testing Station. See the end of this section for an additional photograph of the setup. Prepare three additional testing stations for use in Lessons 18 and 19. Between Lesson 18 and Lesson 19, replace the measurement paper (Lesson 17 Resource E) with the version that includes lines (Lesson 19 Resource).

1. Identify a smooth and level surface, such as a tabletop, for the testing station. An ideal surface would be at least 4 ft in length to accommodate the station itself while also allowing space for the Lesson 17 wooden block tugboat demonstration on the opposite side of the bin.
2. At one end of the surface, stack the two 5 cm × 15 cm × 2 cm wooden blocks so they reach a height of 4 cm.
3. Prop the end of the clipboard on the edge of the top block to form a ramp. Position the clipboard with the clip at the top of the ramp so that the car can slide down unobstructed.
4. Place the plastic bin 12 inches away from the bottom edge of the ramp. Make sure to place the bin right side up with the lid on. To prevent the bin from sliding, place about 5 lb of books or other objects on top of the lid or inside the bin.
5. Position the color copy of Lesson 17 Resource E lengthwise between the clipboard and the bin. Center the page with the clipboard, and slide the top of the page under the bin to cover the white space above the green zone.

   Note: Before Lesson 18, make space for the cushions at all four stations by sliding the color copy of Lesson 17 Resource E about 1 inch away from the bin and toward the ramp. Before Lesson 19, swap out the color copy of Lesson 17 Resource E for the color copy of Lesson 19 Resource. Again, make sure to leave space for the cushion at each testing station. The top of the green zone on the color copy of Lesson 19 Resource should align with the edge of each cushion. The amount of space may vary depending on the thickness of students' cushions.

6. Place two rulers lengthwise so they extend from the end of the clipboard to the bin, creating a track that is just wide enough to allow the Hall's car to move between the rulers' inner edges.
7. Place two strips of masking tape lengthwise on the clipboard, making sure to align the two strips with the two rulers so that students can properly position the car between these strips of tape on the ramp.
8. Tape the clipboard onto the tabletop or other surface so that the clipboard does not move during testing. Make sure that the tape does not interfere with the track for the car. Consider securing the two rulers as well by taping down the outer edges that are next to the clipboard, but make sure that removing and adding Lesson 17 Resource E and Lesson 19 Resource remains easy.

9. Test the ramp by releasing the Hall's car from various points along the clipboard without pushing the car. Find the starting point on the ramp that results in the car consistently bouncing away from the bin and then stopping so that the front of the car is in the middle of the yellow zone.
10. After finding this starting point, mark the line where students should place the back wheels of the Hall's car. To do so, tape the third ruler across the width of the clipboard.



Imagine Stage Testing Bags

Follow the instructions below to set up bags of materials for testing during the Imagine stage in Lesson 18.

Materials: resealable plastic snack bags (8), cotton balls (30), jumbo craft sticks (4), medium wedge erasers (6), nonhardening modeling clay ($\frac{1}{4}$ lb), braided cotton rope (2.5 ft), scissors (1), sponges (2), tape

Materials Note: The quantities above are enough for eight bags of materials: two bags of cotton balls, two bags of sponges, and one bag each of jumbo craft sticks, medium wedge erasers, nonhardening modeling clay, and braided cotton rope. To prepare for Lesson 18, place two bags of different materials at each of the four stations. Disassemble the bags at the end of the lesson so the materials are available for groups to use during the Create stage in Lesson 19.

Alternative material options for this challenge include the following: one 6″ × 3″ piece of felt instead of 15 cotton balls and 10–12 plastic straws (cut to 6″ length) instead of one sponge. However, if selecting an alternative material, be prepared to modify the illustrations in Lesson 18 Activity Guide and to print or draw a new header for the class results chart in Lesson 18.

Preparation

1. Arrange six erasers in a single layer in a bag.
2. Arrange 15 cotton balls in a single layer in a bag. Then repeat, arranging the other 15 cotton balls in another bag.
3. Tape the craft sticks together side by side, and place them in a bag.
4. Form the modeling clay into a roughly 15 cm × 4.5 cm × 0.5 cm slab, and place it in a bag.
5. Cut the rope into six 5″ pieces. Arrange the pieces in a single layer in a bag.
6. Place each sponge in its own bag.

7. Squeeze all the air out of the bags before sealing them. Fold over the tops of the bags and tape the tops down to prevent the materials inside from shifting.
8. Place two bags containing different materials at each Dock Cushion Testing Station before Lesson 18.

Create Stage Materials

Follow the instructions below to set up materials for students to access during the Create stage in Lesson 19.

Materials: resealable plastic snack bags (8), cotton balls (120), jumbo craft sticks (32), medium wedge erasers (48), nonhardening modeling clay (2 lb), braided cotton rope (20 ft), scissors (1), sponges (8)

Materials Note: The materials listed above are enough to accommodate eight groups. Students can use and reuse the resealable plastic snack bags to create eight dock cushions per class. The quantities of the six remaining materials above (cotton balls, jumbo craft sticks, nonhardening modeling clay, medium wedge erasers, braided cotton rope, and sponges) allow for up to eight bags of each. Disassemble the Imagine stage testing bags so that students can reuse the materials they tested in Lesson 18.

Preparation

1. Cut the rope into 5″ pieces.
2. Divide the modeling clay into eight pieces of roughly equal size.
3. Gather the remaining materials: cotton balls, craft sticks, erasers, sponges, and resealable plastic snack bags.
4. For ease of distribution and to encourage sharing, consider placing sets of materials in boxes or bags for each group.

Classroom Procedure

Follow the instructions below to demonstrate how to use the Dock Cushion Testing Station during Lessons 17, 18, and 19.

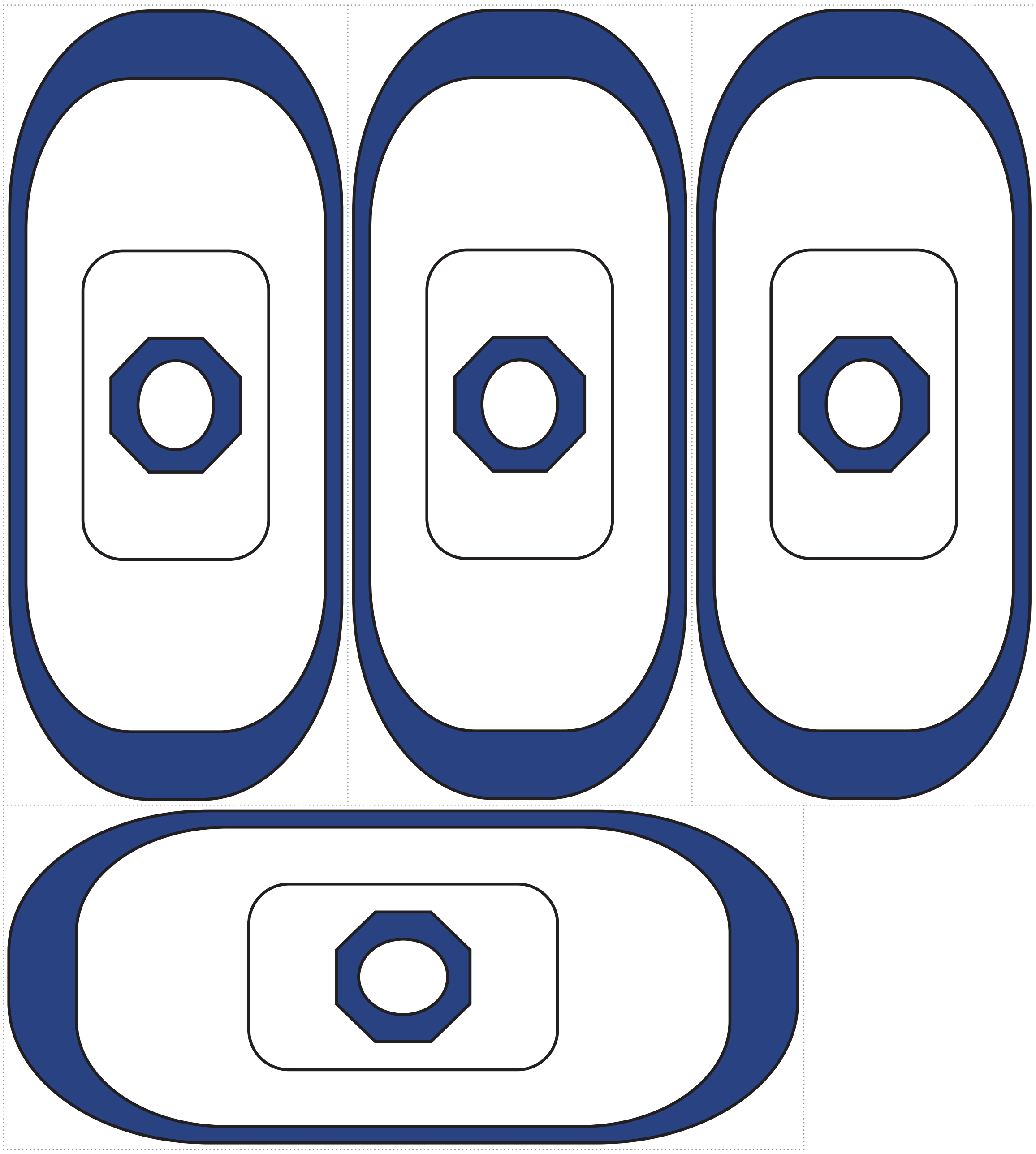
1. Have a student volunteer place the Hall’s car on the ramp. Guide the volunteer to align the back wheels of the car with the bottom edge of the ruler.
2. Instruct the volunteer to release the car without pushing it. The car should roll down the ramp, hit the bin (or cushion, in Lesson 18), and bounce backward.

3. Ask a second student volunteer to observe how far the car bounces and to announce this result to the class.
   a. During Lesson 17, the volunteer should announce the color zone where the front of the car stops. If the ramp has been set up correctly, the front of the car should stop in the middle of the yellow zone when no cushion is in place.
   b. During Lesson 18, the volunteer should announce the color zone where the front of the car stops. Show students how to record the result by marking a sticky note with that color.
   c. During Lesson 19, the volunteer should count the boxes between the dock and the front of the tugboat (including the box that the front of the tugboat is in) and should then announce the total.

LESSON 17 RESOURCE G

Tugboat Cutouts for Engineering Challenge

To help students think of the Hall's cars as model tugboats, consider affixing one of these cutouts to the top of each car before beginning the Engineering Challenge.

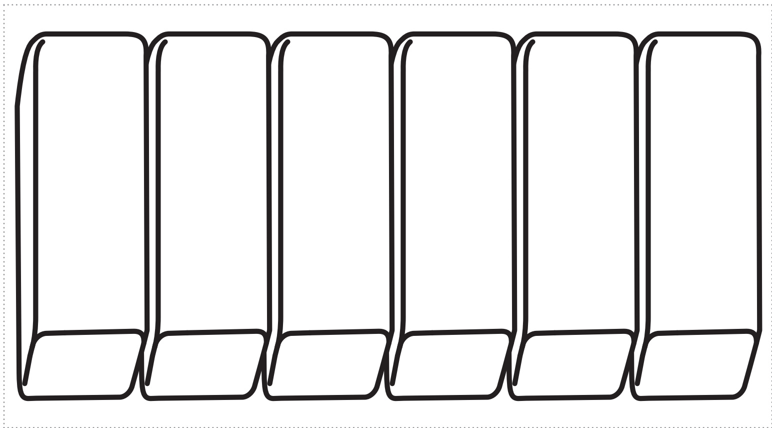


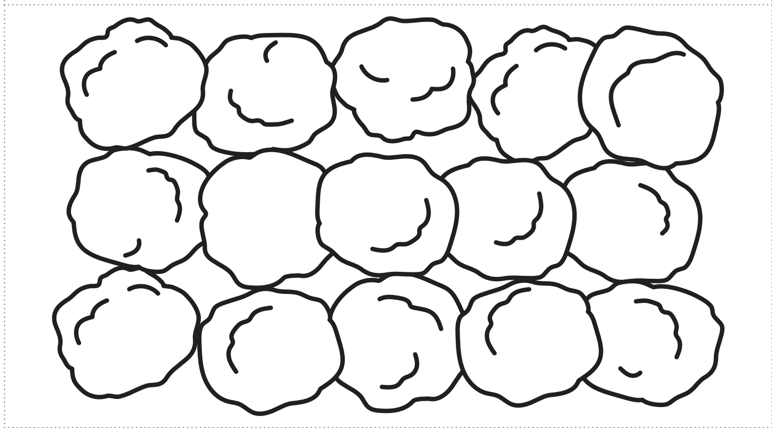
LESSON 18 RESOURCE

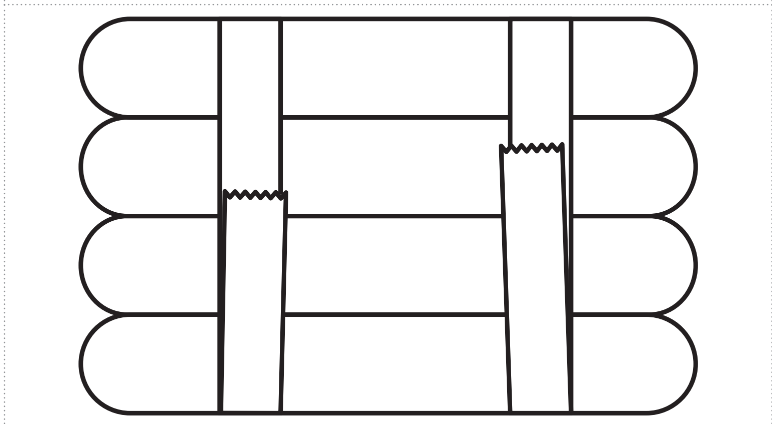
Results Chart Header Illustrations

Print and cut out each illustration to place at the top of each column of the class results chart. Consider using card stock and laminating for multiple uses.

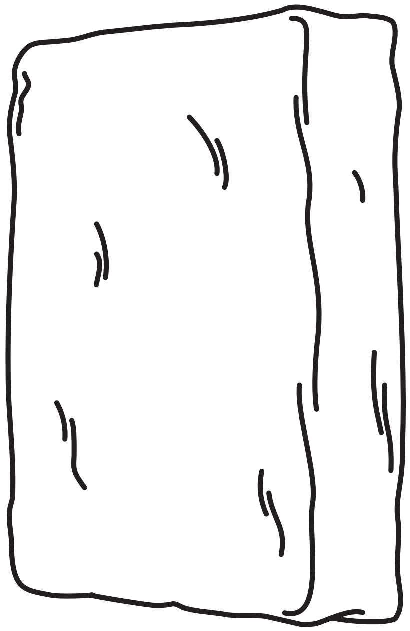
Erasers, Cotton Balls, and Craft Sticks

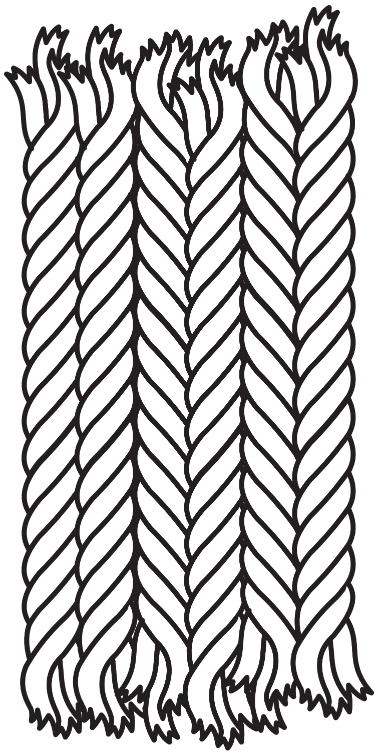


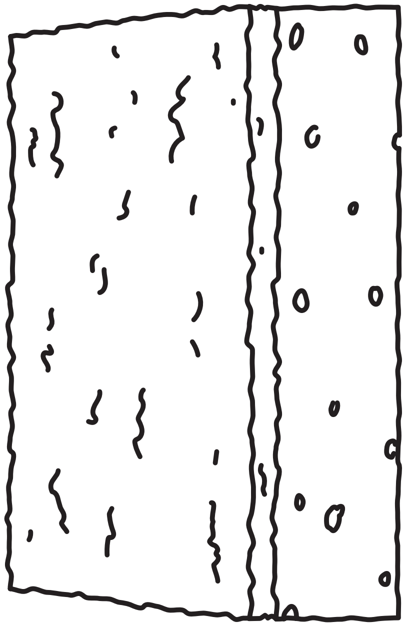




Modeling Clay, Rope, and Sponge

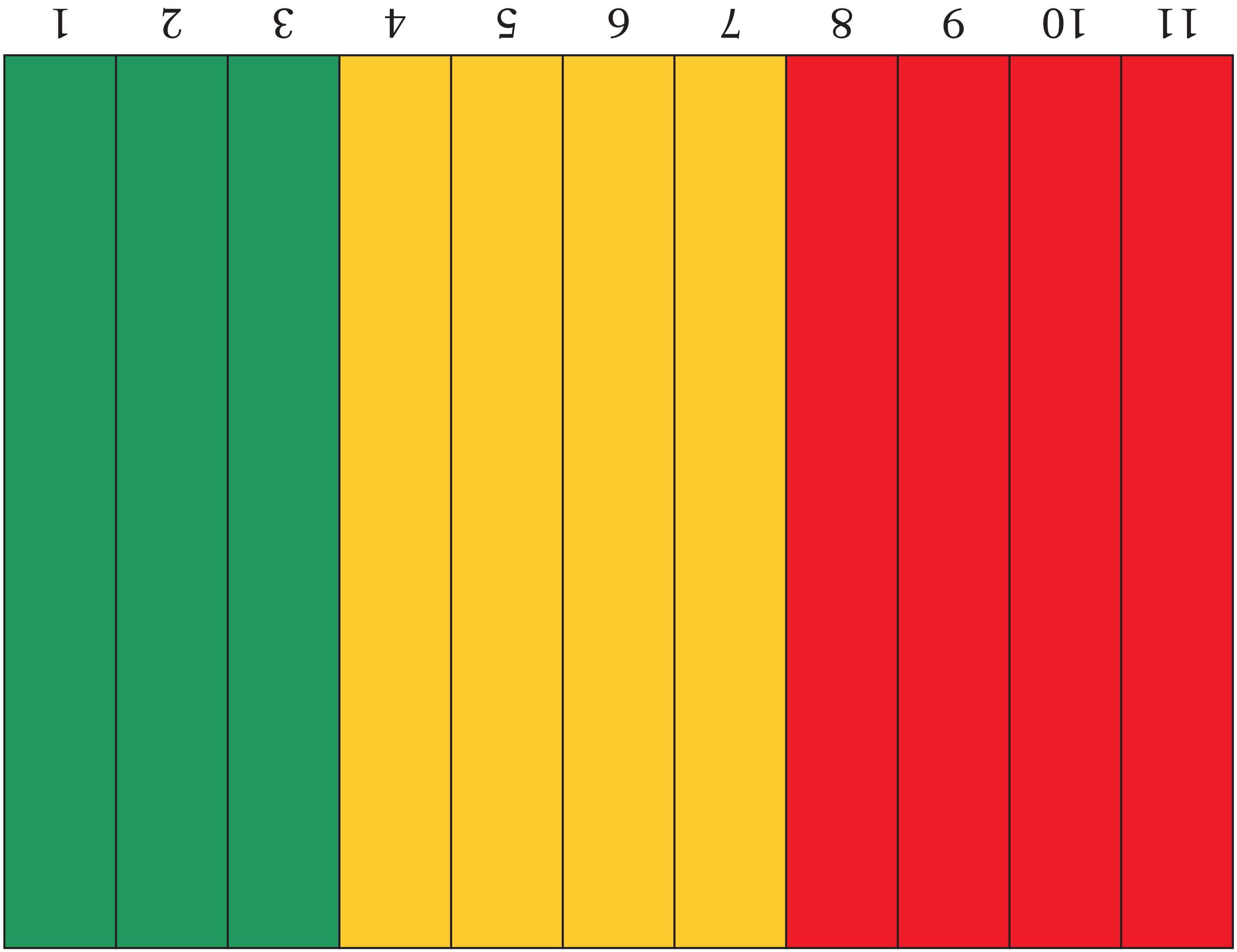






LESSON 19 RESOURCE

Lined Measurement Paper



LESSON 20 RESOURCE

Dock Cushion Photographs

LESSON 21 RESOURCE

Key Term Cards

Print and cut out enough copies of the cards for each student to receive one card. Consider using card stock and laminating for multiple uses. Distribute the cards during the Lesson 21 Launch, making sure to pass out each term at least once.

Direction	Object	Pull
Push	Speed	Strength

LESSON 22 RESOURCE

Carnival Game Photographs

Boat Race

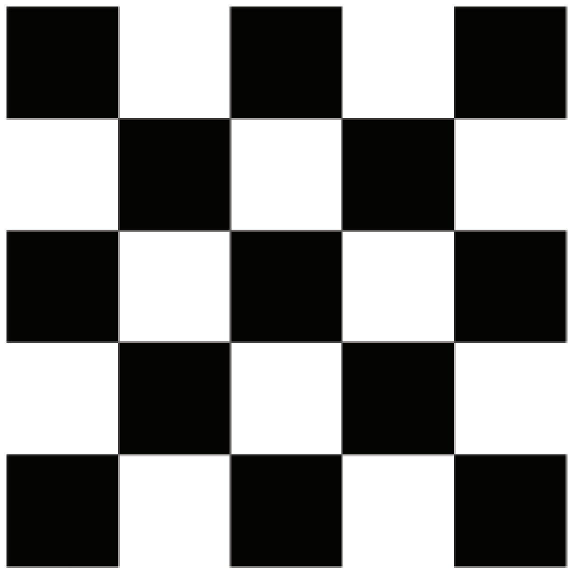
Miniature Golf

LESSON 23 RESOURCE

Crosscutting Concept Cards

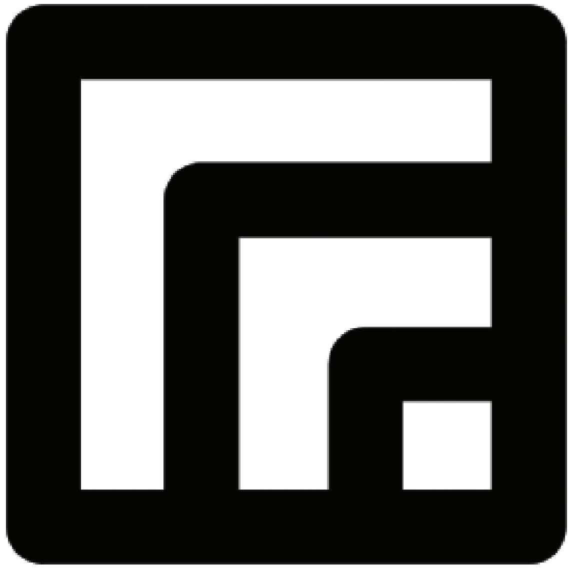
Print and cut out the Cause and Effect card to use in Lesson 23. Consider also printing and cutting out cards for other Crosscutting Concepts students are familiar with. Refer to these cards during relevant moments in future lessons.

Patterns

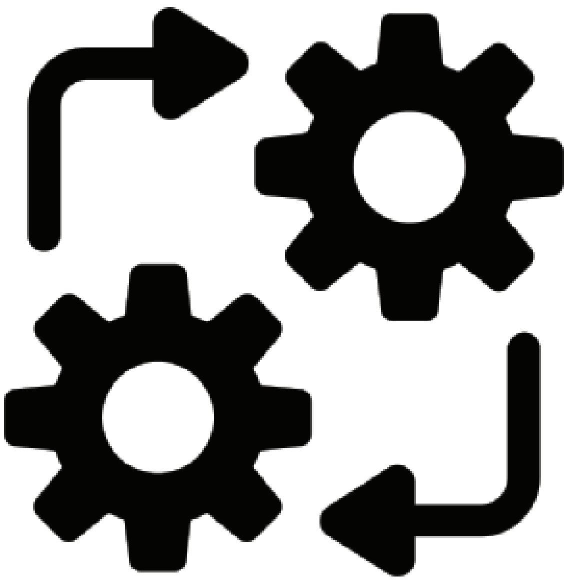


Cause and Effect

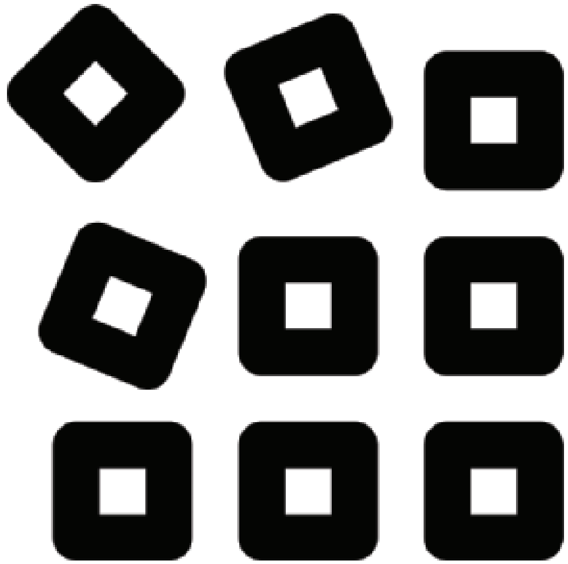
Scale, Proportion, and Quantity



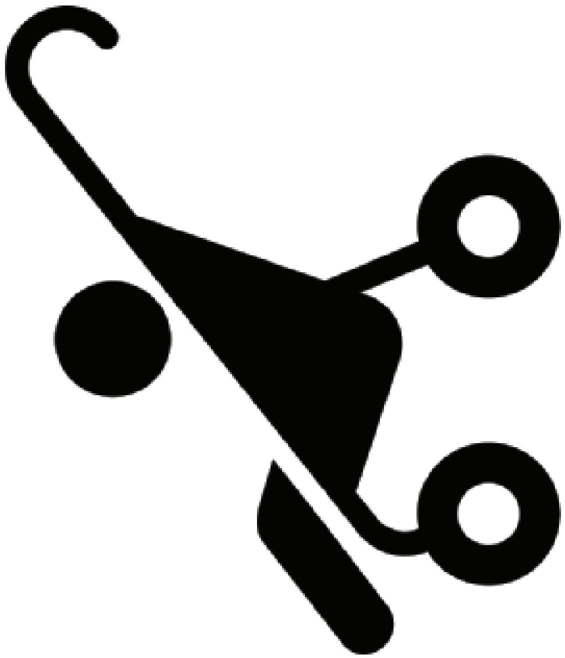
Systems and System Models



Energy and Matter



Structure and Function



Stability and Change

Appendix B

Module Storyline

Anchor Phenomenon: Tugboats Moving Cargo Ships *Essential Question: How do tugboats move cargo ships through a harbor?*
Conceptual Overview Pushes and pulls can cause objects to start moving and can cause their movement to change. 1. Pushes and pulls can cause objects to start moving. The strength of the pushes and pulls can affect the speed of the objects. 2. Pushes and pulls can cause moving objects to change direction or stop.
NGSS Performance Expectations **K-PS2 Motion and Stability: Forces and Interactions** K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull. **K–2-ETS1 Engineering Design** K–2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

Concept 1: Starting Movement (Lessons 1–9)

Focus Question: What causes objects to start moving?

Lessons 1–3

Phenomenon Question: What do tugboats do?

Phenomenon: Tugboats moving cargo ships

Spotlight on Three-Dimensional Integration: Students see multiple instances of pushes and pulls making objects move (PS2.A), and they ask questions (SEP.1) to guide future learning about this pattern (CC.1).

Knowledge Statement: Tugboats help cargo ships move through harbors.

Wonder:* We begin by thinking about how we could move a large object in our classroom, and we discuss why moving a large object in a small space is challenging. Our teacher then reads aloud *Tugboat* by Michael Garland (2014), and we look at examples of a tugboat helping big ships move. We notice that the tugboat uses either a push or a pull every time it moves a big ship.

Organize: Next, our teacher introduces the New York Harbor Knowledge Deck poster, and we learn that tugboats help bring cargo ships to the port so the ships can deliver goods. Then we think about ways we can explore big ships inside our small classroom.

Wonder: Our teacher shows us a map of New York Harbor, and we think about how tugboats move big cargo ships through the narrow harbor. We use a map model that includes wooden blocks, which represent tugboats and cargo ships, to explore different ways that a tugboat can move a cargo ship through the harbor to reach the port.

Organize: We use ideas from our exploration with the wooden blocks to start developing an anchor model. We decide which way we want to show a tugboat moving a cargo ship. Our teacher adds a tugboat cutout and a cargo ship cutout to a harbor map to capture our decision.

Tugboats Moving a Cargo Ship

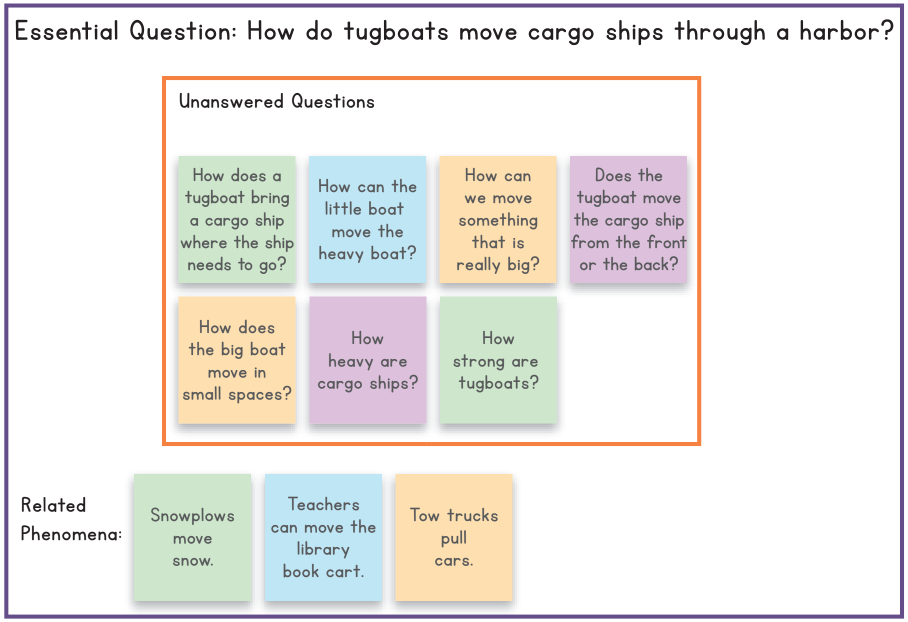
A tugboat moves a cargo ship toward the port.

* The purple headings indicate the relevant content stage within the content learning cycle. See the Implementation Guide for more information on the content learning cycle.

Wonder: Our teacher reminds us that scientists figure out what they need to learn by asking questions. We think about which questions will help us learn about how tugboats move cargo ships and which questions will not.

Next, we think about what we have noticed about tugboats so far. We know that tugboats help move cargo ships through harbors, but we still have a lot of questions about how tugboats do their jobs.

Organize: We share our questions, and our teacher records them on a driving question board. At the top of the driving question board, our teacher writes the Essential Question: How do tugboats move cargo ships through a harbor?



Lessons 4–6	
Phenomenon Question: How do tugboats make cargo ships start to move? **Phenomenon:** Objects starting to move **Spotlight on Three-Dimensional Integration:** Students record observations (SEP.4) of moving objects to identify the pattern (CC.1) that pushes and pulls cause objects to start moving (PS2.A). **Knowledge Statement:** Pushes and pulls can cause objects to start moving.	**Organize:** Our teacher shows us a set of toys, and we discuss ways that we could use the toys to help us understand how tugboats move cargo ships. We agree that there are differences between the toys and the boats, but our teacher explains that exploring the ways that we move other objects can help us understand how tugboats move cargo ships. **Reveal:** We work in groups to explore ways to make the toys move across a sheet of chart paper. Then we discuss and act out the different ways we made the toys move. We create a class push and pull chart to sort the ways we made each toy move, and we realize that we used either a push or a pull in every case. **Distill:** Our teacher tells us that when we notice something that happens the same way many times, we can describe the repeating event as a pattern. We identify the pattern that objects need a push or pull to start moving. Then we use this pattern to predict that the toy car will move when our teacher pushes it. Our teacher explains that this pattern is a clue that we have found a cause and effect relationship—pushes and pulls cause objects to move. **Wonder:** Our teacher shows us a picture of a toy stroller. We think about ways we could make the toy stroller start to move. **Organize:** Our teacher asks us to look around the classroom to find objects we can move with pushes or pulls. We observe our teacher pushing or pulling one of these objects to make it move, and then we draw what we observed. **Distill:** We discuss the idea that sometimes pushes and pulls cause objects to start moving and sometimes they do not. Then we begin an anchor chart to summarize our learning. **Pushes and Pulls** Starting Movement • Pushes and pulls can cause objects to start moving. Next, we identify pushes and pulls as we watch a video of a ballet performance. Each time we notice a push or pull, we decide as a class where to place a push cutout or a pull cutout on the screen. **Organize:** We then revisit the book *Tugboat* and place push cutouts and pull cutouts on pictures that show the tugboat pushing and pulling big ships. As we look at examples in the book, we consider an important difference between how we moved the toys and how real tugboats move cargo ships—tugboats move ships in water, not on paper. We wonder whether our ideas about pushes and pulls hold true in water. **Reveal:** Our teacher introduces the water model—a large bin containing water, a plastic tugboat, and a wooden block cargo ship. We share our ideas about how the tugboat can make the cargo ship move in the water, and our teacher tests each idea. We discover that pushes and pulls also make the cargo ship start moving in the water.

Distill: We use our observations of the water model demonstration to update the anchor model.

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

Lessons 7–8

Phenomenon Question: How can a tugboat make a cargo ship move fast or slow?

Phenomenon: Push and pull strength

Spotlight on Three-Dimensional Integration: To explore how stronger and weaker pushes and pulls can affect an object's movement (PS2.A), students plan and carry out an investigation (SEP.3) and determine that a stronger push makes an object move faster and a weaker push makes an object move slower (CC.3).

Organize: Our teacher shows us a video of a cargo ship moving slowly through New York Harbor. We share our ideas about why cargo ships need to move slowly in the harbor, and we decide to investigate how tugboats can make cargo ships move at different speeds.

Our teacher shows us how we can use craft sticks and table tennis balls to carry out our investigation. Then we develop an investigation plan, and we work with a partner to explore how we can make the ball move faster and slower.

Reveal: We think about ways we could record how we made the ball move at different speeds, and we realize that we used pushes of different strengths. Our teacher shows us cutouts with larger hands that represent stronger pushes and cutouts with smaller hands that represent weaker pushes. We use the cutouts to show that a stronger push made the ball move faster and a weaker push made the ball move slower. We think about why investigation plans are important, and we realize that they allow us to compare our results as a class.

Next, we wonder how stronger and weaker pushes make objects move in water. Our teacher demonstrates stronger and weaker pushes in the water model. We observe that stronger pushes make the cargo ship move faster, and weaker pushes make the ship move slower. Our teacher also demonstrates stronger and weaker pulls, and we see the same results.

Distill: We summarize on the anchor chart what we learned from our observations.

Knowledge Statement: Stronger pushes and pulls cause objects to move faster than weaker pushes and pulls.

Pushes and Pulls

Starting Movement

- Pushes and pulls can cause objects to start moving.
- Stronger pushes cause objects to move faster than weaker pushes.
- Stronger pulls cause objects to faster than weaker pulls.

We then update the anchor model to show that a weaker push or pull makes the cargo ship move slower.

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

The tugboat uses a weak pull. The cargo ship moves slowly.

Lesson 9

Phenomenon Question: How can a push or a pull help in a skateboard race?

Phenomenon: Pushes and pulls in a skateboard race

Spotlight on Three-Dimensional Integration: Students use their understanding that pushes and pulls can make objects start to move and can change the speed of the objects (PS2.A) to analyze cause and effect (CC.2) in a skateboard race, and they ask a question (SEP.1) that could help them determine which team won the race.

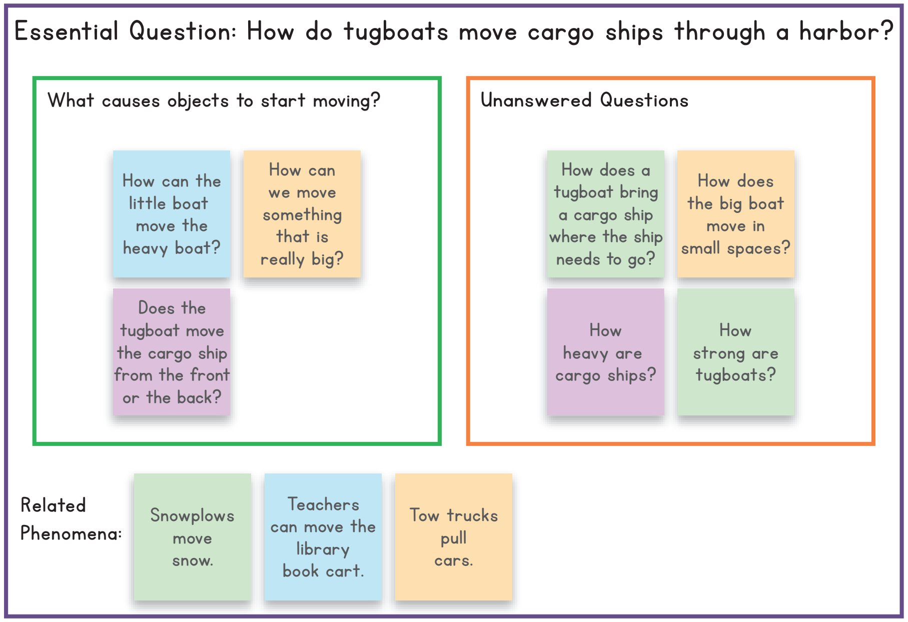
Knowledge Statement: Pushes and pulls can cause objects to start moving. The strength of the pushes and pulls can affect the speed of the objects.

Organize: Our teacher shows us the toys we used to explore movement in a previous lesson. We think about how we used the toys to learn about how tugboats move cargo ships. Our teacher explains that scientists sometimes use what they know about one situation to help them understand another situation.

We prepare for the Conceptual Checkpoint by looking at a picture of children playing with a skateboard. We discuss what we know about racing. Our teacher then asks us to imagine that we each have a partner and are getting ready to have a skateboard race against another pair of students. We look at a diagram that shows the race setup.

Know: We begin the Conceptual Checkpoint by using the diagram to determine whether a push or a pull will cause the children on the skateboards to move toward the finish line. We look at a pair of pictures and identify which one shows the effect of a push. We then ask a question that could help us figure out which team won the race.

After the Conceptual Checkpoint, we reflect on all the different ways we have explored pushes, pulls, and movement. We then return to the driving question board to sort our questions into two groups: those we can answer and those we cannot yet answer. We think about how the questions we can now answer are similar, and we notice that all of them are about starting movement. Our teacher then posts the Concept 1 Focus Question: What causes objects to start moving? We use what we have learned so far to think about how we can answer this question. We share our learning as a class.



Concept 2: Changing Movement (Lessons 10–16) *Focus Question: What causes moving objects to change direction or stop?*	
Lessons 10–12	
Phenomenon Question: How can tugboats turn a cargo ship? **Phenomenon:** Objects changing direction **Spotlight on Three-Dimensional Integration:** Students plan and conduct an investigation (SEP.3) to determine how tugboats can use pushes and pulls to cause (CC.2) a cargo ship to change direction (PS2.A). **Knowledge Statement:** Pushes and pulls can cause moving objects to change direction.	**Organize:** We begin by thinking about how we could walk from one corner of our classroom to another. After a couple of students demonstrate taking different paths through the classroom, we realize that both students had to change direction to avoid bumping into furniture. We then revisit the anchor model and notice that the cargo ship must turn in order to reach the port. We decide to plan an investigation to determine how tugboats can change a cargo ship's direction. We work as a class to develop our class investigation plan. We determine the path the cargo ship will take around the island, and we wonder whether a tugboat can push or pull the cargo ship to make the ship turn. Our teacher shows us that it is hard for one tugboat to turn the ship by itself. We look at a picture of two tugboats pushing a cargo ship, and we decide that we will use two tugboats in the investigation: one to move the cargo ship forward and one to turn it. We then work in groups to plan where we will place our tugboats so that we can turn the cargo ship around the island. **Reveal:** Working in our groups, we follow the class investigation plan and use the map model to test our ideas about turning the cargo ship. We record our observations by gluing small cutouts of tugboats, of pushes, and of pulls on the map in our Science Logbooks to show how we turned the cargo ship. **Distill:** We share our observations and notice that pushing or pulling the side of the cargo ship made it turn. **Organize:** We sit in a circle, and our teacher asks how we can change the direction of a rolling table tennis ball. We suggest pushing the ball from the side while it is moving. Our teacher and a student try this strategy, and it works. Then we wonder whether pushes and pulls can also cause objects in the water model to change direction. **Reveal:** Our teacher asks us to share our ideas for how to change the direction of the cargo ship in the water model. We test some of our ideas and observe that pushes and pulls from the side can turn the cargo ship. **Distill:** We use our learning about how pushes and pulls can turn a cargo ship to update the anchor model so that it shows two tugboats working together to turn the ship.

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

The tugboat uses a weak pull. The cargo ship moves slowly.

The orange tugboat pushes the side of the cargo ship to help turn the ship.

We think about the different objects we have turned by using pushes and pulls, and we add our learning to the anchor chart.

Pushes and Pulls
Starting Movement • Pushes and pulls can cause objects to start moving. • Stronger pushes cause objects to move faster than weaker pushes. • Stronger pulls cause objects to move faster than weaker pulls.
Changing Movement • Pushes and pulls can turn moving objects.

Lessons 13–15	
Phenomenon Question: How can a tugboat make a cargo ship slow down and stop? **Phenomenon:** Objects slowing down and stopping **Spotlight on Three-Dimensional Integration:** Students plan and carry out an investigation (SEP.3) to determine how tugboats can use pushes and pulls to cause (CC.2) cargo ships to slow down and stop (PS2.A). **Knowledge Statement:** Pushes and pulls can cause moving objects to slow down and stop.	**Wonder:** We begin by thinking about how the cargo ship moves as it gets closer to the port. We determine that it needs to slow down as it prepares to stop. Then our teacher shows us a video of a cargo ship crash. We wonder why the cargo ship did not slow down and stop. **Organize:** We decide to use the map model to investigate how tugboats make cargo ships slow down and stop. To help us plan our investigation, our teacher shows us an important difference between the water model and the map model. When our teacher pushes the wooden block cargo ships in both models, we notice that the cargo ship in the water keeps moving but the cargo ship on the map does not. We realize that we will need to give the cargo ship a continuous push to keep it moving across the map during the investigation. In pairs, we then discuss how we can plan our investigation. Then, we share our ideas with the class and develop a class investigation plan. With our partners, we record in our Science Logbooks our plan for using a tugboat to push or pull on the cargo ship so that it stops. Our teacher asks us to share how we made our decisions, and we think about other experiences we have had with making an object slow down and stop. **Wonder:** We look at the picture on the front of our New York Harbor Knowledge Deck cards, and we think about how tugboats stopped the cargo ships at the port. **Reveal:** We then begin our investigation. We take turns handling the tugboat and cargo ship during the investigation, and we test our ideas for how the tugboat can make the cargo ship slow down and stop. We discuss whether our plan worked. We then think about whether pushes and pulls can stop the cargo ship in the water model. As we share our ideas, our teacher tests them, and we see that the tugboat can use pushes or pulls to stop the cargo ship in the water. **Distill:** We use our findings from our investigation and the water model demonstration to update the anchor model so that it shows how one tugboat stops the cargo ship.

Tugboats Moving a Cargo Ship

A tugboat pulls a cargo ship toward the port.

The tugboat uses a weak pull. The cargo ship moves slowly.

The orange tugboat pushes the side of the cargo ship to help turn the ship.

The blue tugboat uses a pull to stop the cargo ship.

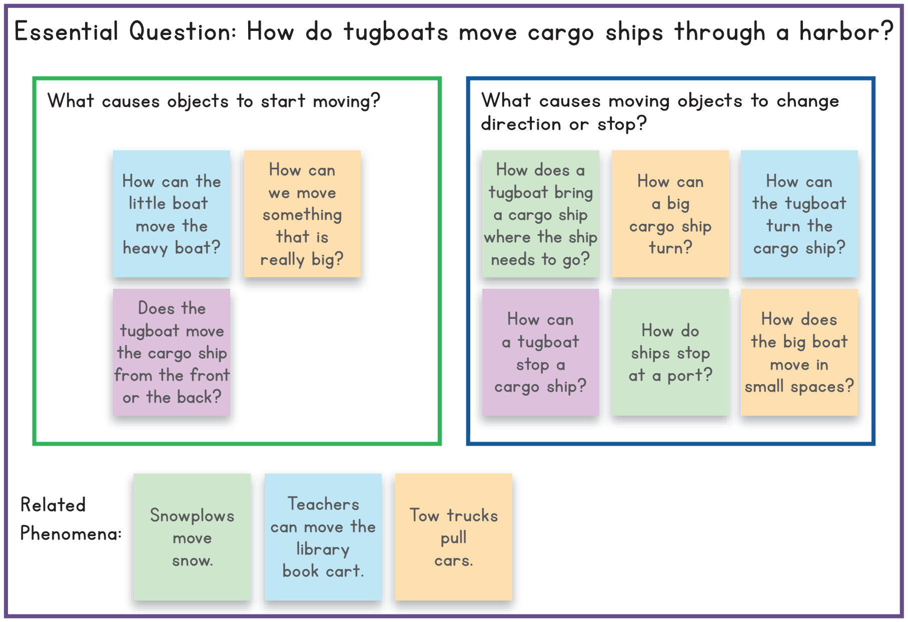
Organize: Our teacher and a student each use a hand to act out the way the tugboat pushed on the cargo ship in our investigation. Then, working in pairs, one student from each pair pretends one hand is the tugboat and the other student from each pair pretends one hand is the cargo ship. We bump our hand into our partner's hand, and we notice that we feel a push from our partner's hand. We switch roles with our partners, and we notice that we feel a push regardless of whether our hand represents the tugboat or the cargo ship. We decide to continue exploring what happens when two objects bump into each other.

Reveal: Our teacher uses the water model to show us what happens when the cargo ship hits the side of the bin. We discover that the cargo ship and the bin both push on each other when they bump, just as our hands did.

Next, our teacher shows us a small plastic car and asks us how we can make the car stop when it is moving. We agree that we can use our hands to push on the car to stop it. We then notice that we feel the car push on our hands when we stop it.

Distill: We think about what we observed and conclude that we can push or pull on objects to slow them down and stop them. We also conclude that when objects bump into each other, each object pushes on the other. We add our new learning to the anchor chart.

	Pushes and Pulls Starting Movement • Pushes and pulls can cause objects to start moving. • Stronger pushes cause objects to move faster than weaker pushes. • Stronger pulls cause objects to move faster than weaker pulls. Changing Movement • Pushes and pulls can turn moving objects. • Pushes and pulls can slow down and stop moving objects. • When objects touch, they both push on each other.
Lesson 16	
Phenomenon Question: How do people use pushes and pulls when they play soccer? **Phenomenon:** Pushes and pulls in soccer **Spotlight on Three-Dimensional Integration:** Students determine whether pushes or pulls cause (CC.2) a soccer ball to start moving and change direction (PS2.A), and they compare images (SEP.3) to identify what happens when a ball bumps into a wall. **Knowledge Statement:** Pushes and pulls can cause moving objects to change direction or stop.	**Organize:** Our teacher asks us to share what we know about soccer and then shows us two videos of people playing soccer. We pay attention to how the players use pushes and pulls to move the soccer ball. **Know:** We begin the Conceptual Checkpoint by looking at a diagram of children playing soccer. We draw lines to show the ball's path as it moves between players. Then we add a push cutout or a pull cutout to show how one player makes the ball start moving. We add another push cutout or pull cutout to show how another player makes the ball change direction. We then think about what happens when a soccer ball bounces off a wall. We determine that when the ball hits the wall, the ball and the wall push on each other. We debrief the Conceptual Checkpoint by reflecting on how soccer players can use pushes and pulls to start moving the ball or to change its direction. We then think about all the different ways we have explored pushes and pulls. Our teacher explains that by studying pushes and pulls in many ways, we are learning how objects move in the world. We return to the driving question board and think about the similarities between the questions we can now answer. We notice that all the questions we can now answer are about how to change an object's movement. Our teacher then posts the Concept 2 Focus Question: What causes moving objects to change direction or stop? We use what we have learned so far to think about how we can answer this question, and we share our learning as a class.



Application of Concepts (Lessons 17–20): Engineering Challenge

Lessons 17–20 (Engineering Challenge)

Phenomenon Question: How can we help a tugboat stop close to a dock?

Phenomenon: Engineering a dock cushion

Spotlight on Three-Dimensional Integration: Students build a device (SEP.6) that changes how a dock and tugboat push on one another when they touch (PS2.B), and students gather evidence about the effects of their designs (CC.2).

Wonder: In the book *Tugboat*, our teacher shows us a picture of the tugboat at its dock. We notice that the boat is very close to the dock so that people can step on and off the boat. Our teacher then shows us a picture of a tugboat in New York Harbor and asks us to imagine that the tugboat captain is in a hurry and needs to return to the dock without slowing down the boat. We start thinking about where the tugboat might stop if it bumps into the dock after moving fast.

Organize: We begin the engineering design process with the Ask stage. Our teacher shows us what happens when a fast tugboat bumps into its dock. We see that the tugboat bounces away from its dock. Then our teacher shows us a picture of a tugboat at a dock, and we notice that both the tugboat and the dock have tires on their sides.

Our teacher creates a problem and solution chart. We identify the problem: When the tugboat bumps into the dock, the dock pushes the tugboat too far away. We decide to design a dock cushion to try to make the pushes between the dock and the tugboat feel weaker. Our teacher shows us a testing station and demonstrates how far a new model tugboat bounces away from its dock without a cushion. We determine that we will know our cushions are successful if they help the tugboat stop closer to the dock than it did during this test.

Next, we move to the Imagine stage. Our teacher introduces different materials that we can use to make our cushions. We decide that we can use the testing station to test the materials, and our teacher demonstrates this idea for us.

Knowledge Statement: People can use the engineering design process to create a device that helps a tugboat stop close to a dock.	**Reveal:** Then our teacher places us in groups. Each group tests a material by sending the tugboat down a ramp so that the tugboat bumps into the material three times. Each time the tugboat bounces away from the dock, we record where the tugboat stops. Then we share our results as a class, and we think about which materials will make the best cushion. **Organize:** We then move to the Plan stage. In groups, we decide which materials we will use to make our cushions. We predict how well our cushions will work and record our thinking in our Science Logbooks. Our teacher then shows us a new way to compare the results we get when we test our cushions. We learn how we can use numbers to measure how far the tugboat bounces in each test. **Reveal:** Next, we move to the Create stage. We work in our groups to create our cushions, test them, and record our results. Then, during the Improve stage, we reflect on our results and make changes to our cushions to try to help the tugboat stop even closer to the dock. We test our improved cushions to see whether they work better. **Distill:** During the Share stage, we perform a Gallery Walk to see other groups' designs and their test results. Then we arrange our cushions in a line. We put the ones that stopped the tugboat closest to the dock on one end of the line and the ones that stopped the tugboat farthest from the dock on the other end of the line. We discuss which materials made the best cushions. **Know:** Finally, we look at pictures of real dock cushions and compare the real cushions with our designs. Then we reflect on how we used our knowledge of pushes and pulls to solve the tugboat captain's problem. We agree that our cushions made the pushes between the dock and the tugboat feel weaker, which helped the tugboat stop closer to the dock.
Application of Concepts (Lessons 21–23): Socratic Seminar, End-of-Module Assessment *Essential Question: How do tugboats move cargo ships through a harbor?*	
Lessons 21–23 (End-of-Module Socratic Seminar, Assessment, and Debrief)	
Phenomenon Question: How do people use pushes and pulls to play carnival games? **Phenomenon:** Pushes and pulls in carnival games **Spotlight on Three-Dimensional Integration:** Students use their understanding of how pushes and pulls can change an object's movement (PS2.A) to communicate information (SEP.8) about the causes of movement (CC.2) in carnival games. **Knowledge Statement:** Pushes and pulls can cause objects to start moving and can cause their movement to change.	**Distill:** As a class, we participate in a Socratic Seminar and discuss our Essential Question: How do tugboats move cargo ships through a harbor? We use our work products from throughout the module to help us answer this question. **Know:** In the End-of-Module Assessment, we show our understanding of how pushes and pulls can make objects in carnival games start moving, change direction, or stop. Then we reflect on our learning from throughout the module. We then discuss any remaining questions about how tugboats move cargo ships through a harbor.

Appendix C

Module Glossary

These Kindergarten-appropriate descriptions of the module terminology are not intended to be complete definitions.

Term	Description	Lesson
Direction	the path someone or something takes when moving	10
Object (n.)	something that people can see or touch	1
Pull (n.)	an action that can move an object closer	4
Push (n.)	an action that can move an object away	4
Speed (n.)	how fast or slow an object is moving	7
Strength	how strong or weak something is	7

Appendix D

Domain-Specific Words, General Academic Words, and Spanish Cognates

Type	Word(s)	Spanish Cognate
Module Key Terms (Tier Two or Three)	Direction	Dirección
	Object	Objeto
	Pull	None
	Push	None
	Speed	None
	Strength	None
Domain-Specific Words (Tier Three)	Cargo	Carga
	Dock	None
	Harbor	None
	Port	Puerto

Type	Word(s)	Spanish Cognate
General Academic Words (Tier Two)	Cause	Causa (n.), causar (v.)
	Effect	Efecto
	Investigate (v.), investigation (n.)	Investigar, investigación
	Predict (v.), prediction (n.)	Predecir, predicción

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Credits

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ON THE COVER

"The Knave of Hearts" pas de deux
Alice's Adventures in Wonderland

Royal Ballet performance, 2011

The Royal Opera House

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